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n R. Geyer

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Geology, Mineral Resources and Environmental Geology of the Palmyra Quadrangle, Lebanon and Dauphin Counties

by Alan R. Geyer
Pennsylvania Geological Survey

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1970

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COVER SKETCH BY ALBERT
VAN OLDEN IS TAKEN
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PREFACE

This report describes the general geology of an area in Lebanon County bounded on the west by the Borough of Palmyra, on the east by the Village of Fontana, on the south by the Village of Bachmanville, and on the north by the Village of Bellegrove. High-calcium limestone, one of Pennsylvania's most valued mineral resources, is found in this area. Detailed maps of this limestone, the Annville Limestone, its characteristics and chemical analyses are given in the report.

Currently the Annville Limestone is being quarried for fluxstone, agricultural limestone, filler material, aggregate and as a stone used to enrich cement rock in the manufacturing of portland cement. Large reserves of high-calcium limestone are available to underground mining. The advantages of mining this limestone are given in the report.

Other limestone formations are present in this quadrangle. These rocks will be a continuing and increasingly important source of aggregate. Part of one rock formation, the Ontelaunee Formation, may be a source of high-magnesium metallurgical-grade stone.

Shales of the Martinsburg Formation have been tested and have proven to be potential sources of brick and sintered aggregate. In the Palmyra area, shales of the Martinsburg Formation may be potential sources of alumina because random samples show about 19.5% Al_2O_3.

A detailed ground water study was conducted in 1963.
An inventory of municipal, industrial, and domestic wells and springs was made during this study. The groundwater potential of each rock formation is given in Plate 1.

Areas in danger of collapse by sinkhole development are mentioned. Other rock properties important in construction, industrial development, and private housing expansion are given in Plate 1.

This report will be of value to all producers in the stone industry as well as all regional and local planning agencies in the area. Effective conservation of our mineral resources can be accomplished only when the geology of these resources is known.

Annville limestone quarry located north of Palmyra.

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Plate 1. Geologic map of Palmyra Quadrangle including cross-sections and environmental geology factor legend. ... (in pocket)

Typical Annville limestone outcrop.

Geology, Mineral Resources and Environmental Geology of the Palmyra Quadrangle, Lebanon and Dauphin Counties

by
Alan R. Geyer
Pennsylvania Geological Survey

ABSTRACT

The area described in this report is in southeastern Pennsylvania and includes parts of Dauphin and Lebanon Counties. Two major physiographic provinces are represented. A narrow belt along the southern edge of the Palmyra Quadrangle is underlain by Triassic rocks that are part of the Triassic Lowland Section of the Piedmont Province. All of the area north of the Triassic Lowland Section is included in the Great Valley Section of the Valley and Ridge Province. The Great Valley, or Lebanon Valley as it is called locally, has an average width of 10 miles and has two physiographically dissimilar parts. The southern part is underlain by limestone and dolomite and is consequently lower topographically. This section of the valley is typified by sinkholes, caves, and valley sinks but is not occupied by any one major surface stream. The northern part is underlain by less soluble shale, sandstone, and minor limestone of the Martinsburg Formation and rises about 100 feet above the limestone valley. Small streams following well-defined valleys are frequent in this part of the Lebanon Valley.

The Triassic Lowland Section has an average elevation and relief greater than that of the Lebanon Valley immediately to the north. The prominent ridges of this Section are underlain by conglomerates, resistant sandstones, metamorphosed sediments and diabase and are for the most part densely wooded.

The rocks exposed in the Palmyra Quadrangle range in age from Middle Cambrian to late Triassic. Quaternary alluvium deposits are present but are of minor importance and thickness and are not shown on the Geologic Map. The rocks are composed of shale, sandstone, limestone, arkose, conglomerate, and diabase. The first four types are the most abundant.

The primary structural feature of the Cambrian and Ordovician rocks in the Lebanon Valley is a major thrusted overfold or nappe. This nappe system appears to extend about 60 miles along strike and is about 10 miles wide near the City of Lebanon. In the area of this report the overturned fold has no appreciable regional plunge

and overall the outcrop belts are fairly regular. Interpretation of these geologic structures is important in prospecting for, and determining reserves of high-calcium limestone in the Palmyra area. Where the structure is complex, this interpretation must be based on detailed geologic mapping of surface exposures, supplemented, if possible, by exploratory drilling. Accurate calculation of reserves and quarry planning depend on this structural analysis.

The Annville Limestone is the only high calcium limestone present in the Palmyra area. Its maximum thickness is 250 feet and analyzes more than 96% calcium carbonate. The Annville limestone is currently being quarried for fluxstone, agricultural limestone, filler material, aggregate and as a stone used to enrich cement rock. Large reserves of high calcium limestone are available in this area to underground mining. This is another method by which the producer can obtain quality stone from the Annville Formation. The advantages of mining the high calcium limestone are many.

Limestone, other than high calcium, and dolomite formations are numerous in the quadrangle. Long term prospects suggest that these rocks will be a continuing and increasingly important source of aggregate. The upper part of the Ontelaunee Formation may become a source of high-magnesium metallurgical-grade stone.

Shales of the Martinsburg Formation have been tested and have proven to be potential sources of brick and sintered aggregate. More and more attention has been placed on high-alumina shales in Pennsylvania with particular emphases on the Martinsburg Formation. In the Palmyra area, this shale may be a potential source because the chemical analyses show random samples to average about 19.5% Al_2O_3.

INTRODUCTION

GENERAL

Limestone and dolomite, many thousands of feet thick, sandstones, shales, conglomerates, diabase intrusives, and recent stream deposits are exposed within the boundaries of the Palmyra Quadrangle. Limestone, dolomite and shale are important economic mineral deposits of the area (Figure 1).

This report on the Palmyra Quadrangle is one more in a series of detailed geological studies in Lebanon and Dauphin Counties. A list of previous published reports may be found in the Pennsylvania Geological Survey's list of geological publications.

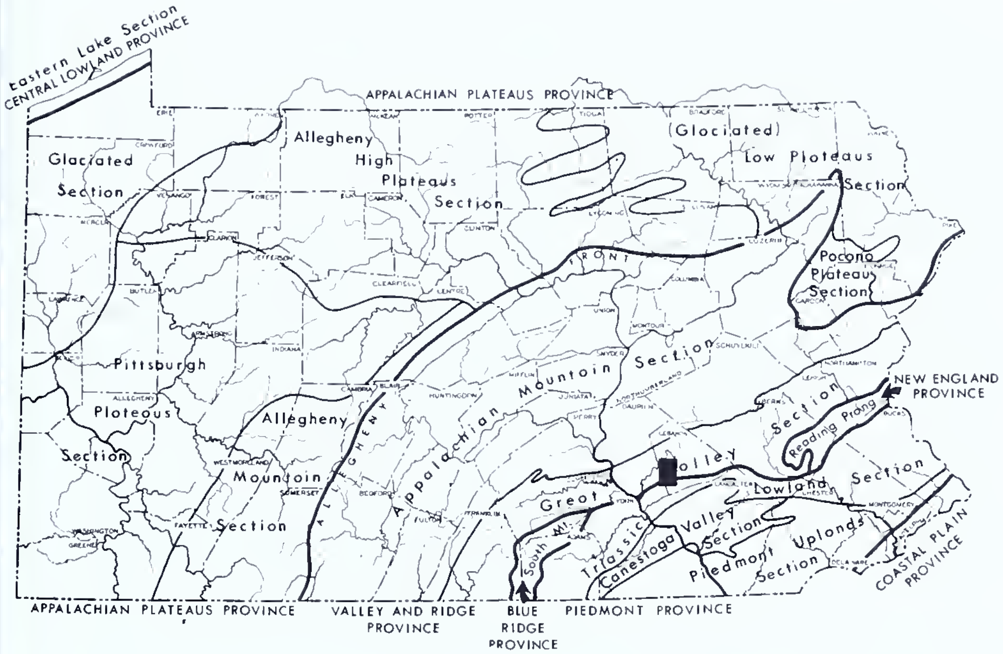

Figure 1. Location of quadrangle.

TOPOGRAPHY

Two major physiographic provinces are represented in the Palmyra Quadrangle. A narrow belt along the southern edge of the quadrangle is underlain by Triassic rocks that are part of the Triassic Lowland Section of the Piedmont Province. The Triassic area is irregularly hilly, with relief of 100 to 300 feet, contrasting with the gently rolling limestone valley to the north. The most prominent hills, with few exceptions, mark the outcrops of the thickest conglomerate members. The boundary between the Triassic rocks and limestone is well marked topographically as the base of a hill-slope over three fourths of the width of the quadrangle. The western one-fourth of the boundary is vague in some places and lies in an area of very gentle slope. All of the area north of the Triassic Lowland Section is included in the Great Valley Section of the Valley and Ridge Province.

The Lebanon Valley varies in width from eleven miles near Palmyra to sixteen miles near Womelsdorf. It is divided physiographically and geologically into two portions: the southern part is underlain by Cambrian and Ordovician limestones and dolomites; and the northern part is underlain by Ordovician shales, sandstones, and limestones.

To the north, the Great Valley is an area of rolling hills (Figure 2) with well-developed dendritic drainage. The tops of the hills average about 550 feet in elevation along the northern border of the belt and about 660 feet just north of the Borough of Annville. The hilltops decrease in elevation toward the main streams—Swatara Creek, Little Swatara Creek, and Quittapahilla Creek. The flood plains of the main streams represent the lowest elevations in the area, and range in width from one-tenth to one-half of a mile.

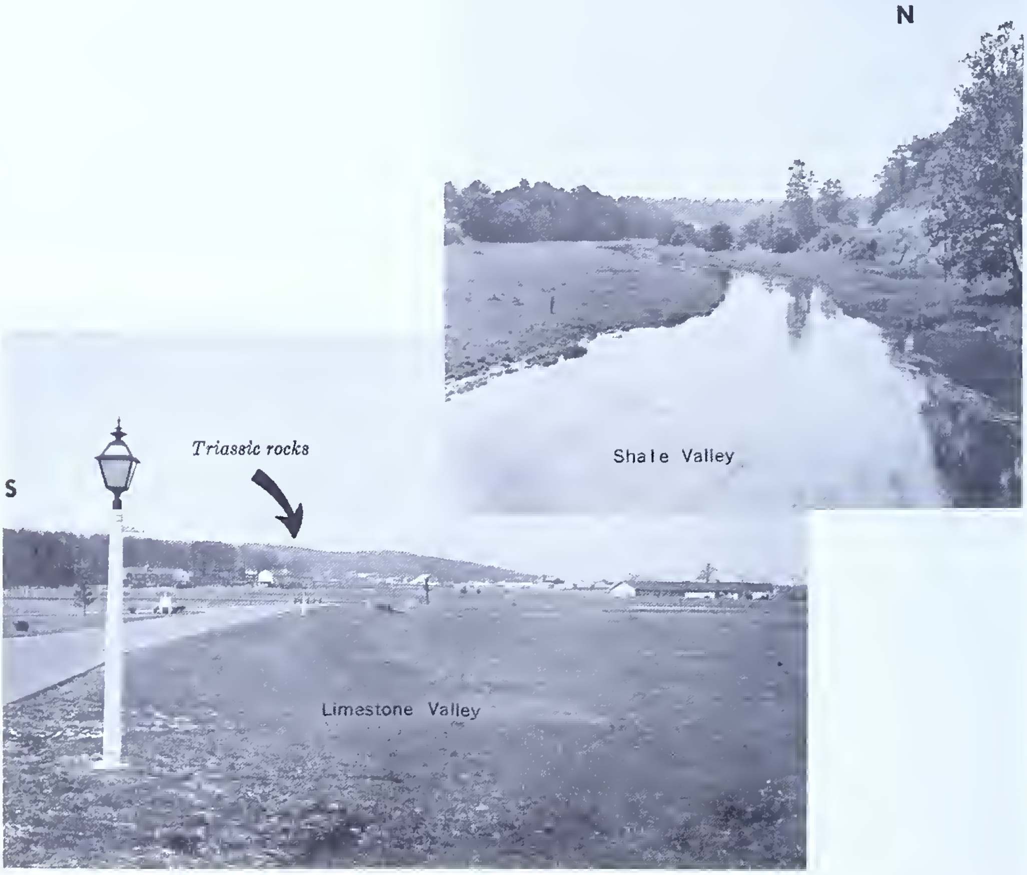

Figure 2. Views of the Great Valley. To the north, the Great Valley is an area of rolling hills with a well-developed drainage. The southern part of the Great Valley is a low, flat, gently rolling limestone valley.

The southern part is a low, flat, gently rolling limestone valley. The low topographic relief of this valley is due entirely to the solubility of a thick sequence of limestone and dolomite. Typical physiographic features are disappearing streams, sink holes, and large collapsed sink holes. A thick soil over the limestone bedrock makes this valley very fertile and large prosperous farms are typical.

ACKNOWLEDGEMENTS

The cooperation of all those people who contributed information or helped in other ways in the preparation of this report is appreciated.

The author assumes responsibility for most of the interpertation and for compilation of much of the geologic map (Plate I), including any errors that may be found.

Cooperating geologists and staff members of the Pennsylvania Geologic Survey have made considerable contributions to this report. Dr. Carlyle Gray introduced the author to the complex structure and stratigraphy of the Killinger Creek area. Much of the geologic mapping of the Annville Limestone north and west of Annville is also Dr. Gray's. Special thanks are due him for giving of his time and experience to the earlier part of this project.

Dr. John R. Moseley (1900-1959) mapped the Martinsburg Formation in this quadrangle. Considerable use was made of his field maps and notes, without which this report may never have been published.

Dr. Dean B. McLaughlin (1901-1965) spent many years studing the Triassic System in Pennsylvania. He is noted for his interpretation of the thick, widespread border fanglomerates. That part of the Palmyra Quadrangle underlain by Triassic sediments was mapped by Dr. McLaughlin and the parts of the text dealing with the Triassic are largely his writings.

STRATIGRAPHY

CAMBRIAN SYSTEM

Buffalo Springs Formation

This formation consists of medium- to heavy-bedded, finely crystalline limestone ranging from very-light-gray to pinkish-gray to medium-gray in color. Interbedded with the limestone is medium- to heavy-bedded light-gray to yellowish-gray weathering dolomite. Shaly laminations that weather light-brown to reddish-brown are numerous.

The base of the Buffalo Springs Formation is not exposed. It is faulted against the Triassic Hammer Creek Formation. The top of the Buffalo Springs Formation is exposed at only one place in the southeast corner of the mapped area. Here, the top is mapped at the base of the first massive, coarsely crystalline dolomite of the overlying Snitz Creek Formation.

A total thickness cannot be determined as neither the base nor the top are exposed in any one area. A minimum thickness of 500 feet is estimated from the width of outcrop.

The best exposures present are found in several small abandoned quarries about 1.8 miles southwest of Campbelltown (Figure 3).

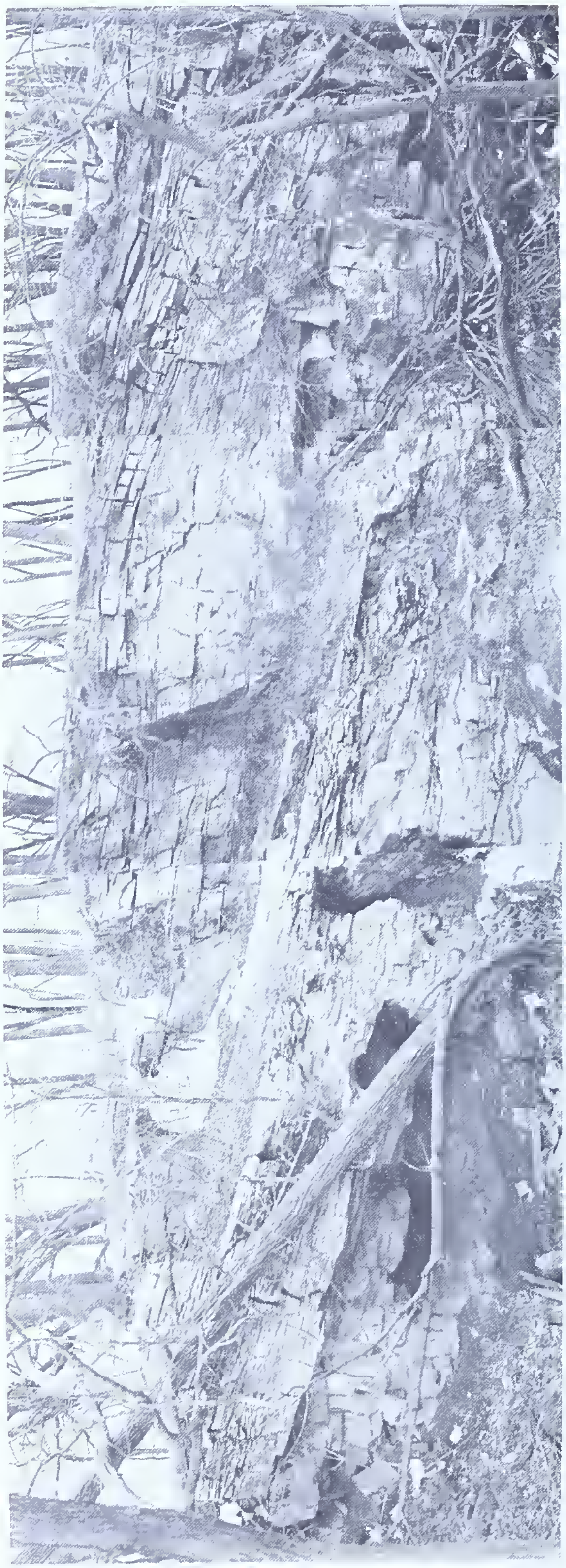

Figure 3. Exposures of Buffalo Springs limestone and dolomite in a small quarry about two miles southwest of Campbelltown.

Conococheague Group

Snitz Creek Formation

Overlying the Buffalo Springs Formation is the dolomite sequence of the Snitz Creek Formation. The dolomite is medium-light gray to light-gray, coarsely crystalline, öolitic and cherty. Extremely coarsely crystalline dolomite is vuggy. Dolomitic sandstone beds more than one foot thick are present near the top of the formation. This dolomitic sandstone is medium-light-gray on a fresh surface but weathers to a light- or moderate-brown color with complete removal of the dolomite cement.

The upper and lower contacts with the Schaefferstown and Buffalo Springs Formations respectively are gradational. The formation is approximately 1300 feet thick near Fontana and about the same northeast of Campbelltown.

The best exposures of the Snitz Creek Formation may be found along U. S. Route 322 between Campbelltown and Mount Pleasant (Figure 4).

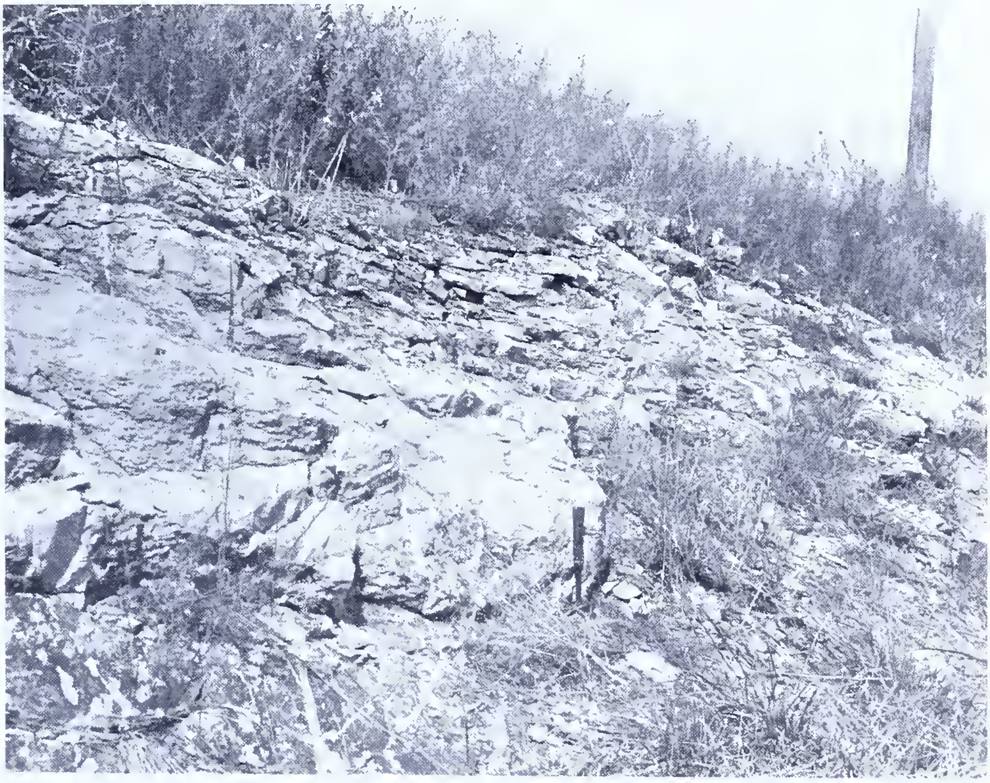

Figure 4. Exposures of the Snitz Creek dolomite along U.S. Route 322 east of Campbelltown. The dolomite is medium-light-gray, coarsely crystalline, oolitic and cherty.

Schaefferstown Formation

The Schaefferstown Formation is a limestone sequence that stratigraphically overlies the Snitz Creek Formation. The few isolated outcrops present in the Palmyra area are typical of this unit as it is exposed in the adjacent Lebanon Quadrangle. These outcrops consist of medium-light-gray to medium-gray, laminated limestone. Distinct shaly bands are often present. The rock is thin to medium bedded. Thin beds of calcarenite are characteristic. The shaly bands and laminae are carbonaceous and make the member particularly susceptible to flowage. The top of the formation is placed at the first bed of white to pinkish-gray, crystalline limestone of the overlying Millbach Formation.

Exposures are poor and a total thickness of 300 feet is approximate. The formation thins rapidly to the west, but it is difficult to establish the relative importance of stratigraphic and structural factors in its disappearance westward.

Millbach Formation

The Millbach Formation is a thick sequence of limestone and dolomite. In the Palmyra Quadrangle this formation which is composed of light-gray to pinkish-gray limestone with medium-gray to dark-gray laminations is interbedded with pinkish-gray, finely crystalline dolomite. The dolomite also contains shaly laminations. Individual beds range in thickness from several inches to two feet. Stromatolites of the cryptozoon type are present near the top of the formation.

The top is placed at the base of the first medium-gray, sandy dolomite bed of the overlying Richland Formation.

A thickness calculation in this quadrangle is not possible because of the complex folding and thrusting. To the east, in the Lebanon Quadrangle, the width of outcrop suggests that it is approximately 500+feet thick.

Exposures of the Millbach Formation are generally good north of Route 322 between the villages of Mt. Pleasant and Fontana.

Richland Formation

The Richland Formation is predominantly dolomite. Very few exposures of the Richland Formation are present in the Palmyra Quadrangle. Outcrops of the lower part of the formation are composed of medium-dark-gray to dark-gray, medium crystalline, massive bedded dolomite which weather light-olive to yellowish-gray.

A major thrust fault has removed much of the formation and no indication of true thickness is possible. To the east, in the Lebanon Quadrangle, the formation is approximately 750 feet thick.

ORDOVICIAN SYSTEM

Beekmantown Group

The entire section of the Ordovician carbonates of the Lebanon Valley is represented in this quadrangle. The name Beekmantown has been widely used in the Appalachian States to designate Lower Ordovician carbonate rocks. The Beekmantown of Berks County was defined as a Group by Dr. John P. Hobson in 1957. He established four formations, Stonehenge, Rickenbach, Epler, and Ontelaunee, which have been mapped throughout Lebanon County. Gradational contacts exist between the Beekmantown Group and the underlying Conococheague Group throughout the Lebanon Valley, except where thrust faulting is present. Through most of the Lebanon Valley, the Beekmantown Group is overlain by the high-calcium Annville Limestone. The contact is abrupt and usually sheared and may represent a disconformity. This group of carbonate rocks in the Lebanon Valley shows an increased thickness southwestward with a decreasing dolomite content in the same direction.

Stonehenge Formation

The Stonehenge Formation exposed in the area consists of medium-gray, crystalline limestone. Two characteristic features of this limestone are the thin, dark-olive-gray colored shale laminae and the flat-pebble breccia beds. Locally, just north of Campbelltown, the shaly laminae are 2 to 3 inches thick and weather in relief. Thin beds and lenses of calcarenite are common. Thin beds of fossil fragmental limestone may also be found near the top and the base of the formation. Dark-gray chert lenses, blobs, and thin stringers are found throughout the formation.

The basal contact of the Stonehenge Formation with the Cambrian sequence is concealed by a major thrust fault. The upper contact of the Stonehenge is gradational into the overlying Rickenbach Formation and is selected at the base of the first massive, medium-light-gray, dolomite bed of the Rickenbach Formation. However, southwest of Annville, the Rickenbach Formation pinches out and the Stonehenge Formation is gradational into the overlying Epler Formation. Here, the contact has been placed above the highest occurence of limestone with olive-gray to dark-gray shale laminae.

The total exposed thickness of the formation in the Palmyra Quadrangle is 1700 feet. The actual total thickness cannot be determined because the lower contact is concealed by the South Lebanon Thrust fault.

The best exposures are found along Killinger Creek in the center of the quadrangle.

Rickenbach Formation

The Rickenbach Formation is present in only half of the map area, as it pinches out just southwest of Annville. Very few exposures are present. Where it is exposed along Bachman Run and Killinger Creek, it consists of medium-dark-gray to medium-gray, finely crystalline dolomite. Several beds are medium-dark-gray, medium to coarsely crystalline.

The formation reaches an approximate maximum thickness of 200 feet in the quadrangle. This thickness may be measured along Bachman Run where the formation is best exposed.

Epler Formation

The Elper Formation is characterized by thick bedded, strongly laminated, finely crystalline limestone interbedded with a medium to thick bedded, laminated, grayish-yellow weathering, crystalline dolomite (Figure 5). Light-gray to nearly white limestones are abundant, particularly in the western part of the quadrangle. These beds have a distinct "pinkish" appearance similar to that of the Buffalo Springs Formation. Nodular chert is present and abundant.

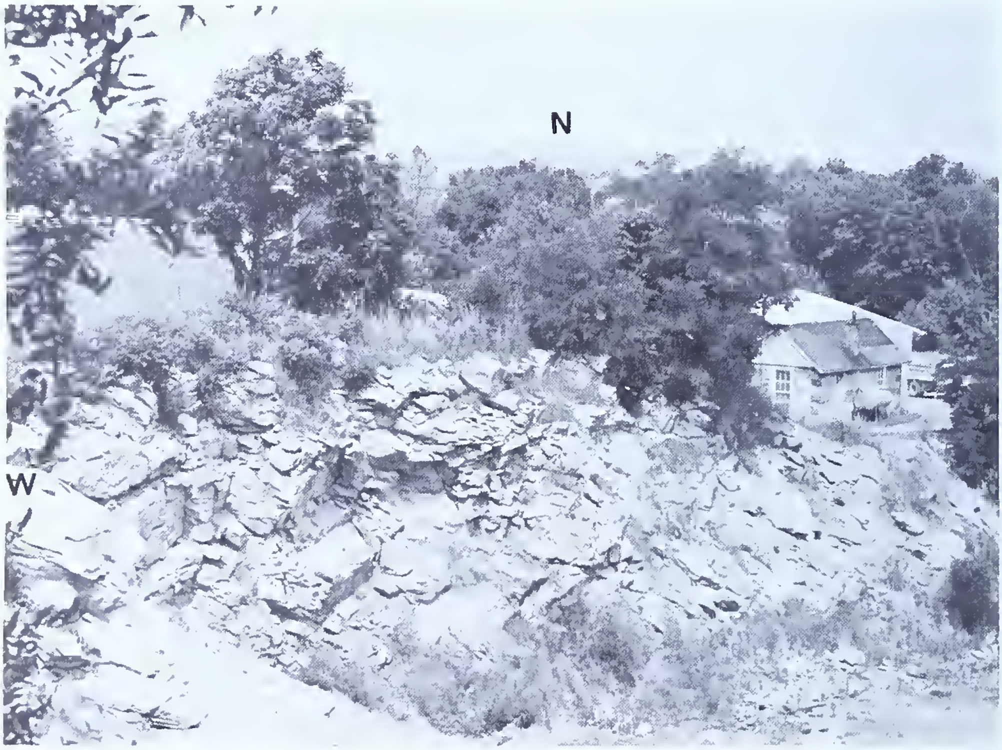

Figure 5. Limestone and dolomite beds of the Epler Formation exposed in a quarry southwest of Annville. West wall of quarry shows recumbent folds.

The base of the Epler Formation is mapped at the bottom of the first massive, medium-gray limestone bed above the Rickenbach Formation. The top is mapped at the base of the lowest of several dark-gray chert beds. This cherty member of the overlying Ontelaunee Formation thins westerly across Lebanon County to approximately two feet at the western edge of the quadrangle.

A full thickness of the Epler Formation outcrops from the eastern edge of the quadrangle to one-half mile west of the Dauphin-Lebanon County line. Exposures of this formation are exceptionally good along Bachman Run and Killinger Creek where the total thickness is about 1300 feet.

Ontelaunee Formation

The Ontelaunee Formation is the youngest subdivision of the Beekmantown Group. The base of the unit is placed at the first occurrence of dark-gray chert that is present throughout most of the Lebanon Valley and is a conspicuous marker for mapping. In the Palmyra Quadrangle, the chert zone reaches a maximum thickness of 24 inches. The best exposures of the chert are along the Reading Railroad tracks west of Palmyra.

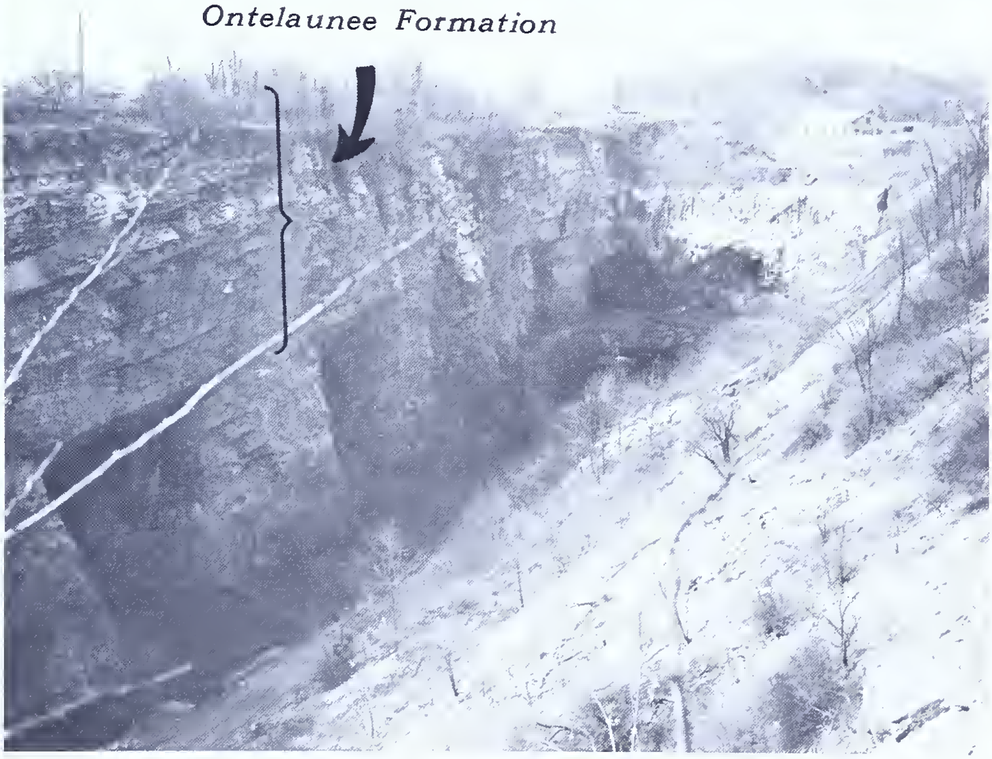

Figure 6. The upper part of the Ontelaunee dolomite is best exposed in the south wall of the Palmyra Quarry, Bethlehem Steel Corp., north of the Borough of Palmyra.

The upper part of the formation may be seen best in the south wall of the Palmyra Quarries of the Bethlehem Steel Corp. between Palmyra and Annville (Figure 6). Here the dolomite is medium-dark-gray, very-finely crystalline, and in beds 1 to 6 feet thick. The dolomite weathers yellowish-gray in color and contains black shale partings between beds. Chemical analyses from these rocks show the composition to be a pure dolomite. Much of the formation below this upper member is covered and very few exposures are present.

The thickness of the Ontelaunee Formation varies from approximately 900 feet at Annville to 800 feet west of Palmyra.

Annville Limestone

The Annville Limestone overlies the Beekmantown Group in this quadrangle. It is a relatively homogeneous, high-calcium limestone formation.

The Annville is predominantly a thick to massive bedded, crystalline, high-calcium limestone, that weathers with smooth or fluted surfaces. Light gray to almost white colors are dominant on weathered surfaces (Figure 7).

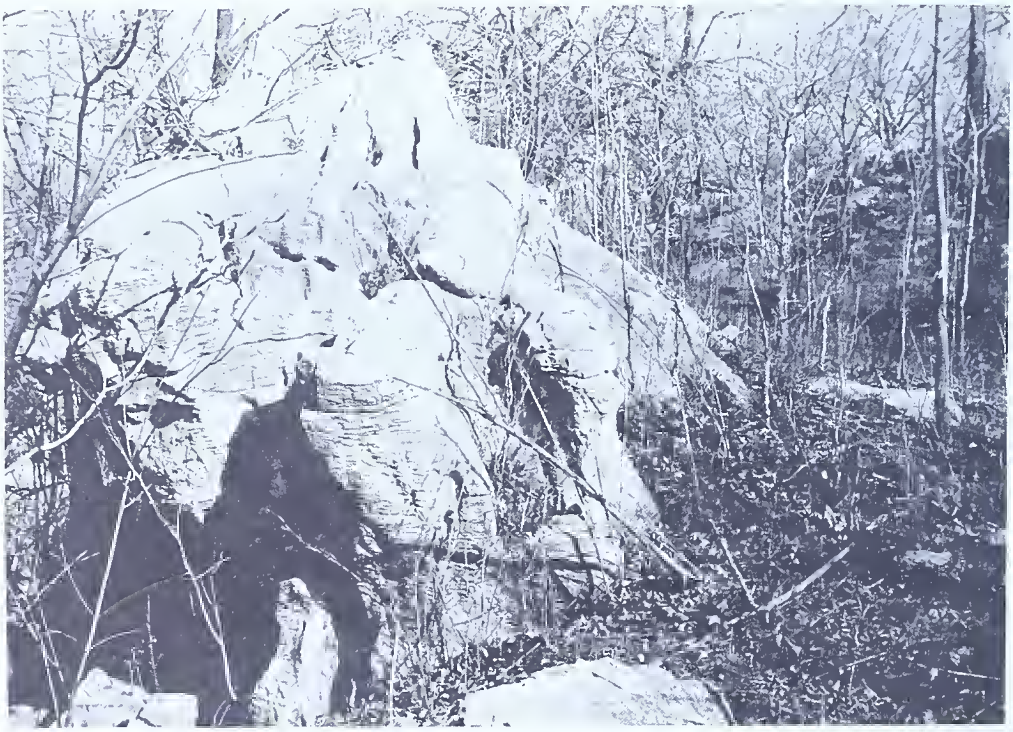

Figure 7. Massive bedded, high-calcium limestone of the Annville Formation exposed west of the Palmyra Quarry, Bethlehem Steel Corp. The fluted weathered surface and the almost white color are characteristic of this limestone formation.

In the area immediately west of Annville and in the quarries adjacent to Route 422, the appearance of the limestone is altered. The rock is bleached, soft and friable but is still of high purity. The alteration of the limestone in this locality is probably due, indirectly, to the structural complexity of the area.

The upper contact with the Myerstown Limestone is abrupt. Light-gray to white, high-calcium limestone beds are adjacent to dark-gray almost black limestone of the Myerstown Formation.

The base of the formation is marked by a very-light-gray to white crystalline bed or beds mottled or streaked with medium-to medium-dark gray.

The Annville Limestone has a stratigraphic thickness of about 240 feet. Stratigraphic and structural complexities account for an eastward thinning of the formation.

Outcrops of the Annville may be found in the Palmyra quarries north of Route 422 between Palmyra and Annville. This formation is quarried extensively for flux stone, lime, and roadstone.

Myerstown Limestone

The Myerstown Limestone is typically dark-gray, dense, thin bedded and carbonaceous. Occasionally beds of calcarenite are present near the base. Rock fragments in the soil above the limestone consist chiefly of rounded and platy pieces that ring when struck with a hammer. Dense, white vein quartz with a columnar or striated texture is commonly associated with this float.

The Myerstown Limestone is gradational into the more shaly Hershey Limestone and in the absence of good exposures the contact is not easily defined.

This formation ranges from 200 to 250 feet in thickness. Variations in thickness are due to local structural complexities.

Exposures of the lower Myerstown Limestone are found in and near the north wall of all the Palmyra quarries (Figure 8).

Hershey Limestone

The Hershey Limestone is poorly exposed in this quadrangle. Where present as float, it is dark-to very-dark-gray, impure, shaly, limestone. Weathered fragments are medium-gray to yellowish-gray or light-olive-gray, and sometimes completely leached of calcite. Most fragments, however, have a darker, calcareous core. Both the fresh and weathered rock fragments are very similar to the dark colered shales of the Martinsburg Formation.

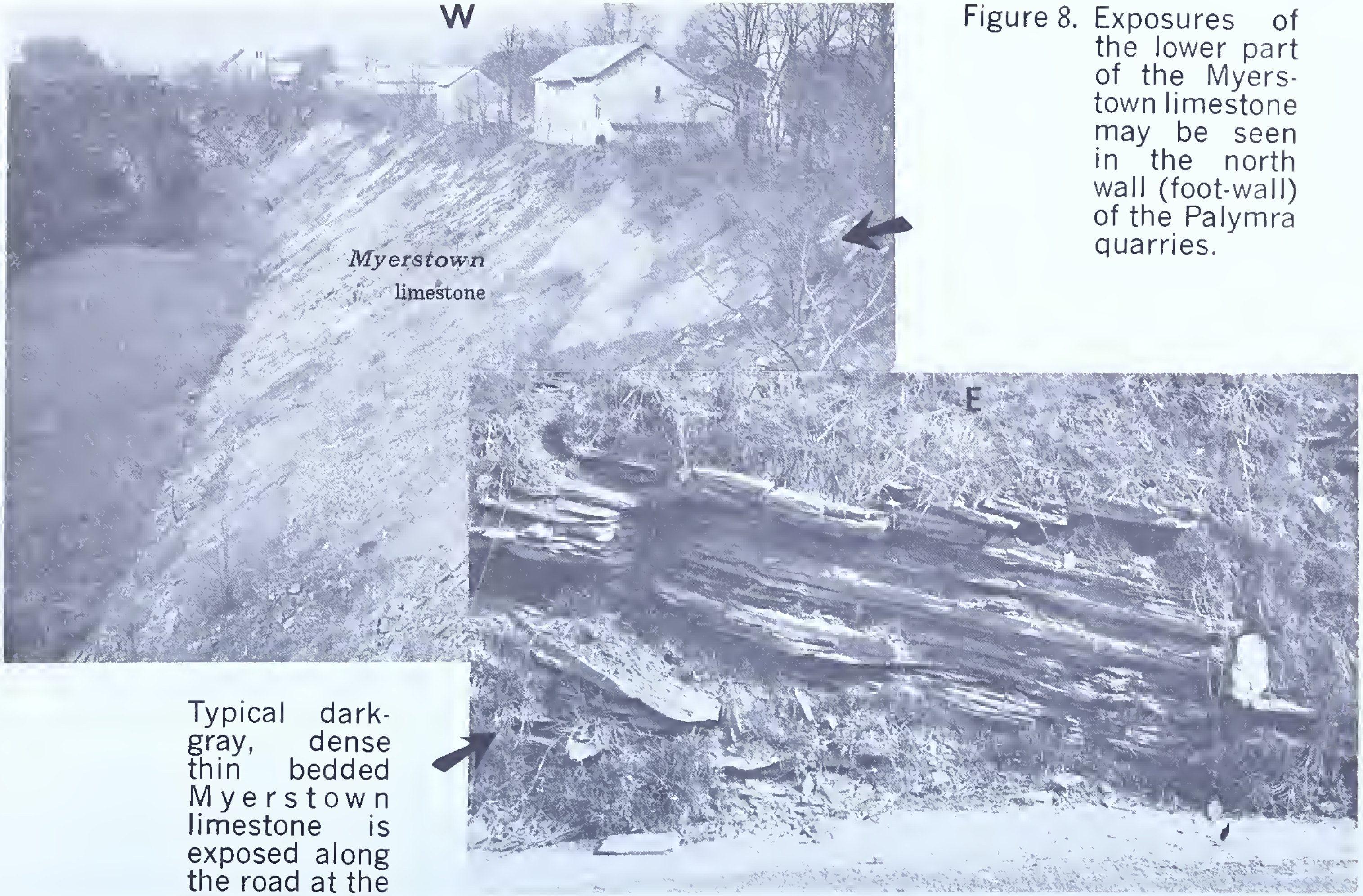

Figure 8. Exposures of the lower part of the Myerstown limestone may be seen in the north wall (foot-wall) of the Palymra quarries.

Typical dark-gray, dense thin bedded Myerstown limestone is exposed along the road at the east end of the Palmyra quar-

Float fragments from the Hershey Limestone can be distinguished from the Myerstown Limestone float by their greater angularity and the fact that they do not ring when struck with a hammer.

There are no outcrops of the Hershey Limestone in the quadrangle. Calculations based on the width of the outcrop belt show the thickness of the formation to be approximately 200 feet.

Martinsburg Formation

General

A group of sedimentary rocks known as the Martinsburg extends from Tennessee northeastward through Pennsylvania and the Palmyra Quadrangle into New Jersey as a belt of variable width along the northern side of the Great Valley. The type Martinsburg Formation is a uniform dark-gray shale unit that is calcareous at the base and sandy and silty in the upper part. However, between the Cumberland Valley to the west and the slate district to the east, a large area of the shale belt is lithologically different from typical Martinsburg. Included in this different sequence are most of the Martinsburg rocks exposed in this quadrangle.

In addition to the uniformly gray, argillaceous shales, siltstones, and sandstones of the typical Martinsburg, there are abundant red and green shales, several varieties of limestones, bedded cherts, thick-bedded quartzites, and conglomerates.

Stose (1946, 1950) recognized that these rocks did not fit the normal Martinsburg sequence and proposed that a major part of the shale belt from the vicinity of the Susquehanna River to the Lehigh River was part of a major Taconic thrust sheet which he designated the Hamburg Klippe.

A recent study (MacLachlan, 1967) suggests that much or all of this anomalous lithology is associated with the Yellow Breeches Thrust plate.

Shale

The shale of the Martinsburg Formation has a varied character (Figure 9). Some of it is slightly arenaceous, some of it is calcareous, but, by far, the greatest proportion of it is argillaceous, breaking down into a clay soil. Some of the shale is thin-bedded and possesses a distinct fissility. Some is massively-bedded and breaks into irregular fragments with a deep conchoidal fracture.

In weathered outcrops the shale displays a wide range of colors including light- and dark-brown, yellow, red, orange, green and olive-gray. In many cases these colors are the result of alteration of an original light or dark-gray color. Individual chips may be found which show the transition of

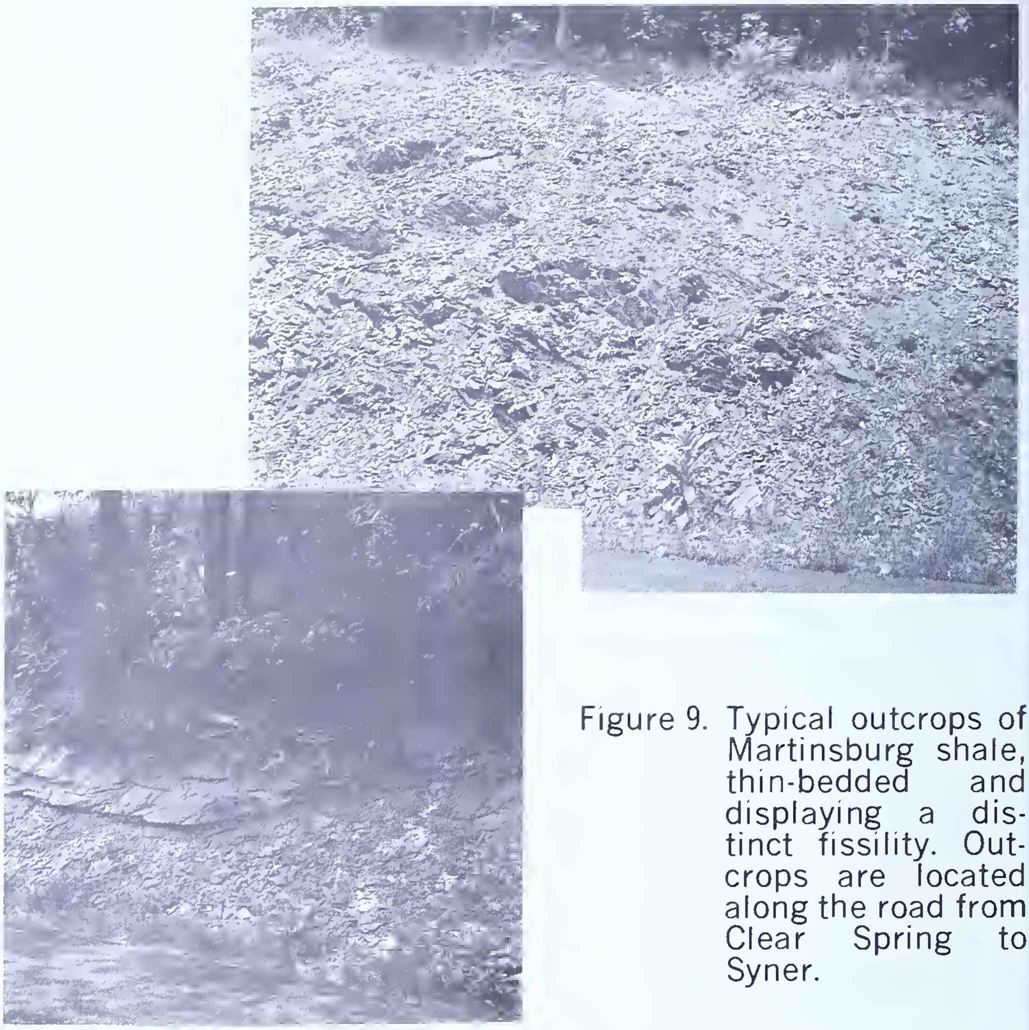

Figure 9. Typical outcrops of Martinsburg shale, thin-bedded and displaying a distinct fissility. Outcrops are located along the road from Clear Spring to Syner.

color from the unweathered center to the altered surface. In a number of outcrops several tens of feet of section show no intercalated sandstone or limestone. Individual beds of shale range from mere partings between sandstone or limestone layers to beds which are six or eight inches thick.

Sandstone

The sandstones of the Martinsburg Formation range from fine-grained graywacke to coarse-grained, pure quartz sandstone and to coarse-grained arkosic sandstone. Gray is the common color of the fresh unweathered surfaces, but much of the rock is weathered to a buff or yellowish-brown color. Pure quartzose sandstone does not occur in the Palmyra Quadrangle but is present as an important ridge-maker to the east in the Bunker Hills south of Jonestown.

Arkosic sandstone, with pebbles and grains of unaltered feldspar as large as one-quarter of an inch, is the most prominent of the sandstone units. Some beds of arkosic sandstone are massive and reach thicknesses of ten to twelve feet. Where exposed in highway cuts it is usually light brown in color and considerably weathered. Only in close association with the intruded igneous rocks is the feldspar fresh and unweathered.

Conglomerate

Conglomerate in the Martinsburg Formation consists of two types: a shale-sandstone conglomerate in a graywacke matrix; and a flat-pebble breccia limestone. Individual beds range in thickness from one or two feet to as much as ten or more feet. Distribution of conglomerate beds is erratic, and this unit appears to have little value in stratigraphic correlation in the quadrangle.

Limestone

The limestones of the Martinsburg Formation consist of three lithologic types: (1) interbedded limestone and shale; (2) limestone breccia or flat-pebble breccia; and (3) massive, pure limestone. The three types are associated with each other and the best exposures are found in the abandoned quarries where the limestone was burned for agriculture lime (Figure 10).

The most abundant of the three types is the interbedded limestone and shale which has been observed in nearly every outcrop where limestone occurs. This limestone is dense, dark gray and occurs in layers that range in thickness from one-fourth of an inch to six inches. The interbedded shale is black and may or may not be calcareous. The shale ranges in thickness from minute partings to layers which are as much as six inches thick.

The flat-pebble breccia occurs in beds which range in thickness from two inches to two and one-half feet. The fragments of limestone are tabular in shape and show little or no rounding of the corners and edges. They range from one-quarter of an inch to one inch thick and from one inch to four inches long. The matrix is often composed of finer, sand-size grains of the same limestone or of poorly sorted argillaceous sandstone.

The more massive, nearly pure, limestone consists of beds of dark-gray limestone with little or no interbedded shale.

These three types of limestone are found in abandoned quarries in this quadrangle. Descriptions of two of these quarries will present a clearer picture of the limestone's characteristics.

The quarries north of Quittapahilla Creek and south of Fairview School contain the interbedded limestone and shale type of deposit. The

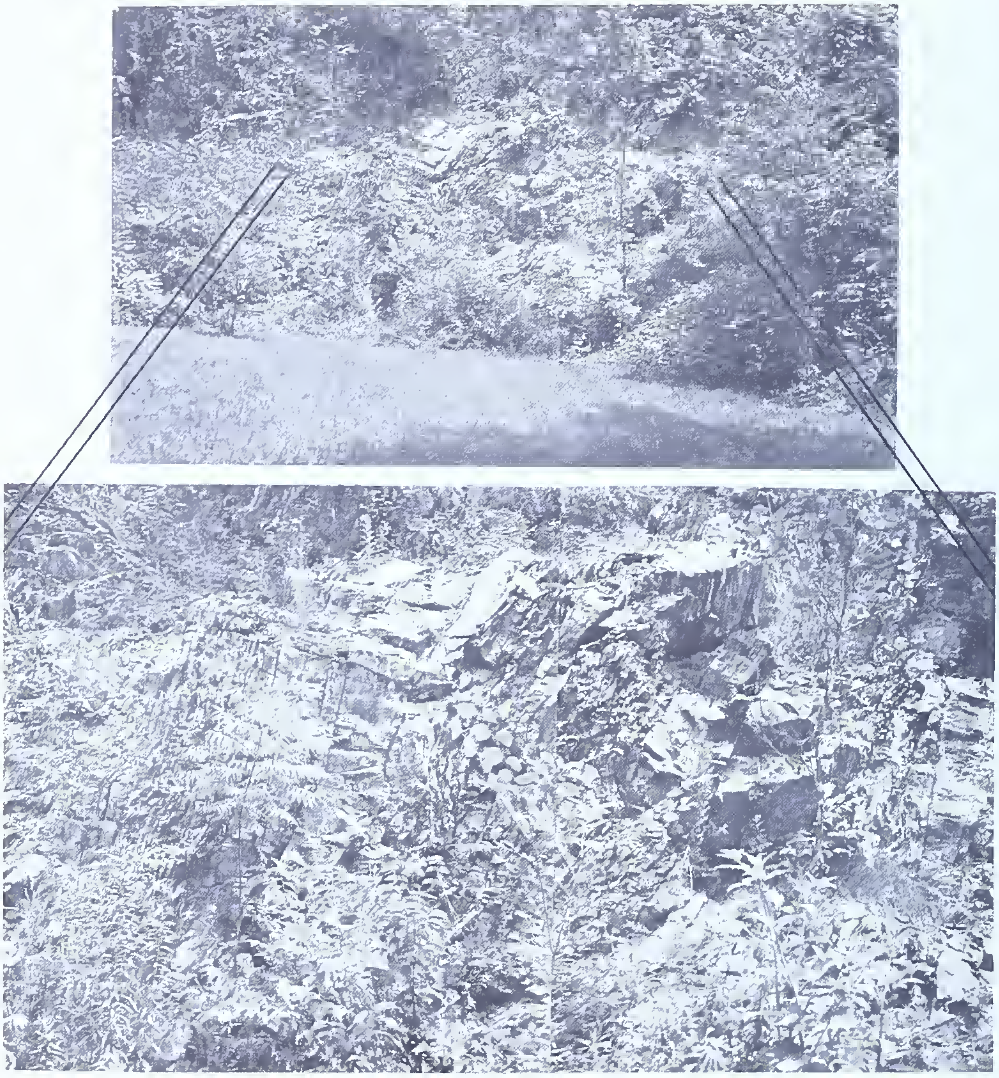

Figure 10. A small quarry in Martinsburg limestone is located along the road leading from Quittapahilla Creek northeast to Fairview School.

larger of the two quarries is located in the corner of the road paralleling Quittapahilla Creek and the road extending northeast to Fairview School. In this road corner facing Quittapahilla Creek just west of a small run which empties into the Quittapahilla is an outcrop (see Fig. 10) of dark-bluish-gray to black limestone interbedded with shale and sandy shale. The entire series of rocks is overturned and the top is to the southwest. At the west end of the quarry, gray to black shale interbedded with calcareous, fine-grained sandstone is exposed. The following section was measured in this quarry from the top of the sequence to the bottom:

Unit		Thickness (Feet)
1.	Interbedded limestone and shale, dark-blue-gray to black with one limestone layer showing nodule-like masses (west of run).	20′
2.	Interbedded, thin, black shale and fine-grained, calcareous sandstone with few scattered layers of black limestone 1″ to 5″ thick.	52′
3.	Black limestone in beds which range in thickness from ½″ to 3′. Thicker beds tend to be laminated and contain numerous calcite veins. Near bottom of sequence the coarse layers are breccia with angular fragments of limestone ⅛″ to 1″ thick and 1″ to 6″ long. The matric is black and contains rounded quartz grains. The limestone layers are separated by shale that ranges in thickness from mere partings to beds 3″ thick. At one time this limestone was crushed and used as roadbed material.	81′
4.	Platy limestone interbedded with black shale in beds 1″ to 2″ thick. Shale beds ranging in thickness from partings to layers 3″ thick, in general becoming more important downward. At the base of this sequence is about 10 feet of medium-bedded limestone (up to 8″) with little shale.	75′
		228′ Total

Another quarry occurs south of Bellegrove where about 20 feet of interbedded limestone and shale are exposed. The limestone layers range in thickness from two to three inches with two beds almost two feet thick near the base of the quarry.

Representative specimens of each of the limestone types have been analyzed for insoluble residue by the late Dr. Moseley. The amount of insoluble residues ranges from 11.5% to 46.3% with an average of 26 analyses being 24.0%. Estimates of the percentages of coarse and fine residues gives an average of about 60% sand and silt and 40% clay. The coarse sand fractions were found to contain zircon, feldspar, pyrite, garnet, muscovite and tourmaline in addition to quartz. In one sample of the residue and in a polished section from the same outcrop, fragments of fossils were observed.

PRE-TRIASSIC ROCKS OF UNCERTAIN AGE

Mill Hill Slate

At one locality in the southeast corner of the Palmyra Quadrangle is a rock formation designate the "Mill Hill Slate". It is a hard, light-gray to black, banded hornfels. The hornfels is frequently laminated and rich in carbonate or calci-silicate minerals. Alternating bands are usually silica-poor and silica-rich but are sometimes calcium-poor and calcium-rich. The thin laminae are relics of an original varied composition. At some localities, primary cross-bedding structures have been preserved.

This rock unit is of doubtful age and origin. It is seen only in the contact zone of the intrusive diabase. The correlation of the Mill Hill Slate cannot be solved structurally because it is in fault contact with the Buffalo Springs Formation which itself is overturned. Therefore, the only possible correlation must be based on lithologic similarities.

The original formation appears to have been a laminated, in part conglomeratic, limy shale. No other unit in the immediate vicinity fits this description but certain limy parts of the Martinsburg shale or Hershey Limestone most closely resemble it.

Further study is needed to solve the intriguing problem of the exact age and origin of this rock unit.

TRIASSIC SYSTEM

Hammer Creek Formation

The Hammer Creek Formation consists of interbedded red shales, red, brown, and gray sandstones, and fine to coarse quartz conglomerates.

Red shale is thin-to medium-bedded, usually friable, and has a hackly fracture. The thin-bedded variety usually has wavy or uneven bedding planes. Ripple marks and mudcracks are present. The shales are usually non-micaceous and nearly always interbedded with siltstone and fine-grained sandstone.

Sandstone is the most widespread rock and is the dominant component in much of the area (Figure 11). In color, the sandstones range from red through brown to light-gray. The red and brown sandstones are the most common. Bedding of the sandstone ranges from one or two inches to a foot or more in thickness. Grain size ranges from very fine to coarse; in general the thinner-bedded varieties tend to be fine-grained. The rock is composed of angular to subround, colorless quartz grains, with a small percentage of miscellaneous mineral fragments, inbedded in a matrix of clay minerals, usually with some hematite. The amount of hematite is the chief cause of the variations of color. Sandstone grades, on the one hand, into siltstone with a larger percentage of matrix, and on the other into conglomerate. The finer sandstones and siltstones are well-sorted but the coarser varieties are rather poorly sorted. Cross-bedding, lensing, and channelling are fairly common. Ripple marks occur on some of the beds.

Coarse quartz conglomerate forms hills and ridges in the quadrangle. This rock is thick-bedded, and is occasionally so massive that bedding is difficult to recognize in small exposures. Almost everywhere, minor sandstone interbeds occur. Pebbles of quartz, quartzite, and sandstone are densely to sparsely distributed in bands and lenses from an inch or two up to many feet in thickness.

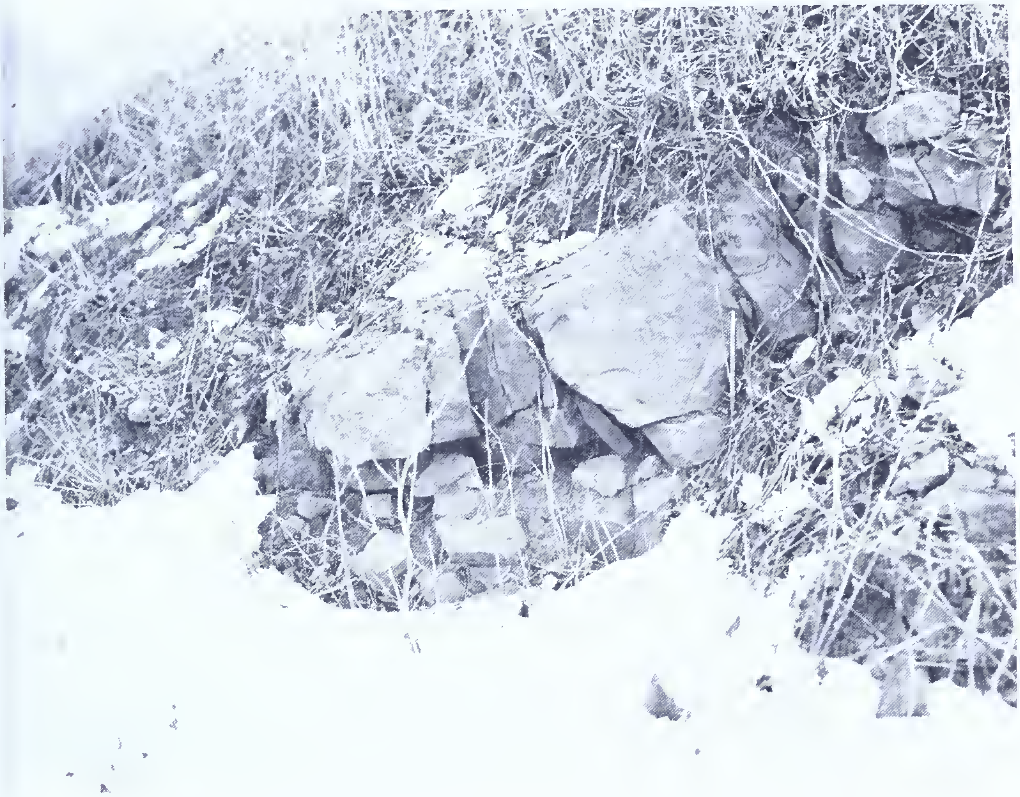

Figure 11. Typical sandstone outcrops in the Hammer Creek Formation. Outcrops are located along the road from Campbelltown to Plainville.

Pebbles up to two or three inches in diameter occur in the most prominent conglomerate member which forms the 900-foot high hill at the east edge of the quadrangle. In most of the other conglomerate members the pebbles usually do not exceed an inch in diameter. Bands and lenses of large pebbles alternate with beds containing smaller pebbles, or with beds of sandstone with few or no pebbles. Occasional beds have pebbles almost touching with only enough groundmass to fill the interstices. More commonly the groundmass forms much more than 50 per cent of the rock.

The conglomerates grade into pebbly sandstone, with a decrease in the amount and size of pebbles. The groundmass of the conglomerate which is essentially that of the coarser sandstones consists chiefly of angular to subround grains of quartz, tiny grains of quartzite, and occasionally fine sandstone and other rocks, bound together by a matrix of clay minerals colored by hematite. Some of the light-gray conglomerates appear to be cemented by silica.

The smaller pebbles in the conglomerates are chiefly colorless, white or pinkish-white quartz. The larger pebbles are commonly fine-to medium-grained light-gray quartzite closely resembling the Tuscarora quartzite which is exposed only 12 miles to the north. A small percentage of pebbles are brown to red, fine-grained sandstone that resembles rocks in the Bloomsburg, Clinton, or Catskill Formations. No limestone or dolomite pebbles were found in this area, although the adjacent rocks to the north are limestone and dolomite. Several miles farther west, in the Hummelstown Quadrangle, are limestone conglomerates which probably represent small, local lenses or steam channel deposits.

No completely exposed section of the Hammer Creek Formation occurs within the Palmyra Quadrangle. From the width of outcrop, and taking account of a local syncline near the north border, a thickness of 4500 feet is estimated for the Hammer Creek Formation. The oldest exposed rocks (one mile west of the southeast corner) are at a computed stratigraphic height of 3000 feet above the base of the formation.

Diabase

Large and small intrusive bodies of diabase occur in the area. The diabase is medium- to dark-gray and fine-to coarse-grained, composed chiefly of gray plagioclase feldspar and black or greenish-black pyroxene and has an ophitic texture. It contains much disseminated titaniferous magnetite which can often be found concentrated in small runnels in the fields after a heavy rain. The outer zones of the large intrustion, and the entire mass of the narrow dikes, are fine-grained and much darker gray in color. Next to the sediments, the grain of the chilled contact facies may be invisible to the naked eye and the rock may superficially resemble the adjacent tough black hornfels.

The diabase is very massive. It weathers into large spheroidal boulders that cover wide areas and make the land unfit for cultivation. The land is usually heavily wooded. Where the rock is more throughly decayed a bright orange-brown clayey soil results from the oxidation of the iron minerals and decomposition of the feldspars. Excavations where the rock is deeply weathered show a gray-green stiff clay that is relatively impervious to moisture. Level areas underlain by diabase are therefore usually poorly drained.

Two large bodies of diabase lie partly in the Palmyra and partly in the Elizabethtown Quadrangle to the south. Both intrusions have irregular boundaries but their longer dimensions are parallel to the strike of the sediments. The presence of contact-chilled diabase around the borders shows that the irregular boundaries are largely the original borders of the intrusions and are not due to later faulting. Both bodies are roughly lenticular in apparent outline and probably in actual form. No exposures of the contacts were found and their attitudes are problematical. A recent aeromagnetic survey, however, shows a magnetic low along its northwestern edge. This indicates that the intrusion is more probably an irregular dike or stock that dips southeastward under the northwest-dipping sandstones.

The diabase area north of the Triassic sediments southeast of Campbelltown appears to be, in part, a swarm of dikes intruding the limestone. Such an interpretation is supported by the complete absence of measurable magnetic effects. Along U.S. Route 322 at the north edge of the area there appear to be three dikes cutting the limestone. In the fields to the south, limestone and diabase float are mixed over a large area.

The small irregular areas of diabase directly south of Mount Pleasant lie north of the northern end of the magnetic high that parallels the larger intrusion to the southwest. Again, it may be suspected that the diabase extends southward beneath the sediments. North of these small areas an occurrence of magnetite is found in a pit where the Mill Hill slate is quarried. This locality appears on Spencer's (1908) map as the Carper Mine.

From the vicinity of the Carper Mine southeastward to the edge of the quadrangle, a narrow and poorly indicated dike and two small patches of diabase are found. A magnetic high lies southwest of these, again pointing to a probable southerly dip of the diabase mass, of which these small areas are the only surface expression. There probably is diabase close to the surface here because the sandstones nearby are considerably indurated by baking.

About a mile west of the southeast corner of the quadrangle is a small irregular area of diabase. Its boundaries, for the most part, are well-defined. Three narrow probable sills of black, fine-grained diabase extend southwestward from the main body along the strike of the sediments which are exposed in two outcrops. Conjecturally this can be regarded as a small stock connected with the larger mass that is inferred to dip southeastward beneath the western limb of the Colebrook Anticline.

The western tips of a few narrow dikes enter the quadrangle from the east about three fourths of a mile north of the southeast corner. These are members of a swarm of small dikes in the Lebanon Quadrangle. A narrow dike near the southeast corner is the end of a large irregular dike in the Elizabethtown Quadrangle.

Contact metamorphic effects are conspicuous arond the larger intrusions. Shale is baked to a tough, dark-gray hornfels. Sandstones have been altered to a brittle white or light-gray quartzite. The large amount of altered sandstone south of the 900-foot high hill at the east edge of the quadrangle indicates that a large intrusive mass probably lies only a short distance beneath the surface in this area.

STRUCTURE

GENERAL

The principle structural feature of the Cambrian and Ordovician rocks in the Lebanon Valley is a major thrusted overfold or nappe. Similar nappes have been recognized in younger mountain systems such as the Alps. This nappe system (Figure 12) appears to extend about 60 miles along strike and is about 10 miles wide in the Lebanon Valley near the city of Lebanon where a maximum rock thickness is exposed. If the rocks in the Lancaster Valley to the south also belong to this nappe system, the width is in excess of 30 miles.

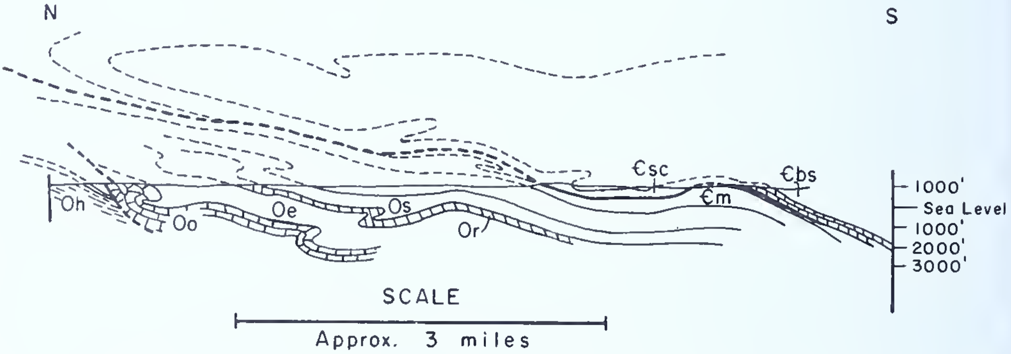

Figure 12. Generalized diagram of the Lebanon Valley nappe.

Minor folds are mappable and may be seen at many places in the Lebanon Valley. Both the large and smaller folds are cut by major faults. Within the area of this report, the overturned fold has no appreciable regional plunge. This lack of regional plunge is reflected in the overall regularity of the outcrop belts.

Locally, the outcrop patterns are complicated by minor folds. These folds are plications of the major overturned anticline. Faults of various types also cause local complications. Variations in the thickness of the carbonate formations are due to flowage in folding and to faulting.

Interpretation of these geologic structures is important in prospecting for, and determining the reserves of high calcium limestone in the Palmyra area. Where the structure is complex, this interpretation must be based on detailed geologic mapping of surface exposures, supplemented, if possible, by exploratory drilling. Accurate calculation of reserves and quarry planning depend on this structural analysis.

GREAT VALLEY SECTION

Folds

The geologic map of the Palmyra Quadrangle shows the general dip of the carbonates and shales to be southeastward with progressively older formations exposed to the southeast. The conclusion is that the entire rock sequence is overturned. Many outcrops in the mapped area do not show overturning by primary sedimentary features but may show this to be true by structural evidence.

Small folds are associated with the much larger nappe. Several of these are mappable in the Palmyra Quadrangle. The most notable one is in the Annville Limestone immediately west of Annville with smaller less conspicuous ones located in the area northeast and southwest of Mt. Pleasant. Both of these smaller subordinate folds are large enough to show in the map pattern of the rock unit. Microfolds can be seen on close examination of laminated limestone.

The structure west of Annville is a recumbent anticline and syncline. The plunge of the fold is variable as seen by the detailed cross-sections in Fig. 13. These cross-sections are taken from Progress Report 140 by Gray (1952). Section A-A' shows north dipping beds of Annville Limestone in an old quarry immediately south of the railroad tracks, near the northeast end of the chain of quarries. These north dipping beds of Annville Limestone contain drag folds with axial planes dipping north at a lower angle than the bedding. This present attitude of the fold can be explained by arching of the axial plane of the recumbent fold. In Section B-B' the Myerstown limestone core of the recumbent syncline has been almost entirely squeezed out. A remnant is visible in the north face of the quarry. Section C-C' shows the structure west of the cross faults.

In the Palmyra Quadrangle the folds may be classed as normal folds. This includes the folds described above as well as the ones near Mt. Pleasent. These folds have axes that are approximately parallel to the regional strike of the rocks and usually have a fairly low plunge. There axial planes dip southeasterly at a low to moderate angle, and are sometimes recumbent and slightly tilted northwestward (Figure 14 and 15). These folds have been produced by normal response to the regional movement of the rocks and also as smaller drag folds associated with the major thrust of the area.

Moseley was able to plot a number of anticlines and synclines in the Martinsburg Formation which gives a general pattern to the folded character of the rocks. Most of these folds are overturned but over three-fourths of the measurements of dip register angles of more than 45 degrees. The large angle dips indicate tightly compressed folds as the rule in the entire Martinsburg Formation in this quadrangle.

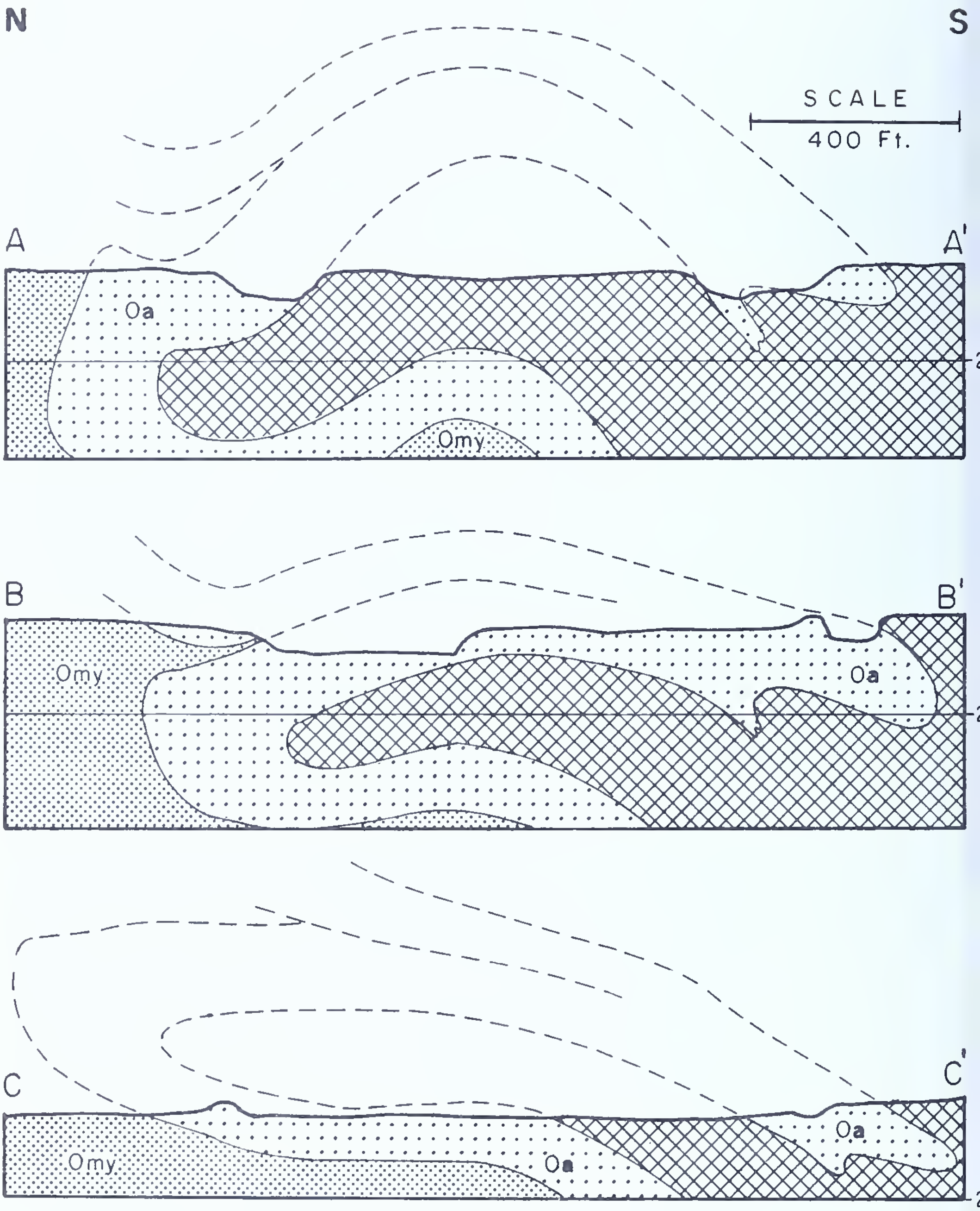

Figure 13. Detailed cross-sections through the quarries immedi- ately west of the Borough of Annville. Taken from Penn- sylvania Geologic Survey Progress Report 140.

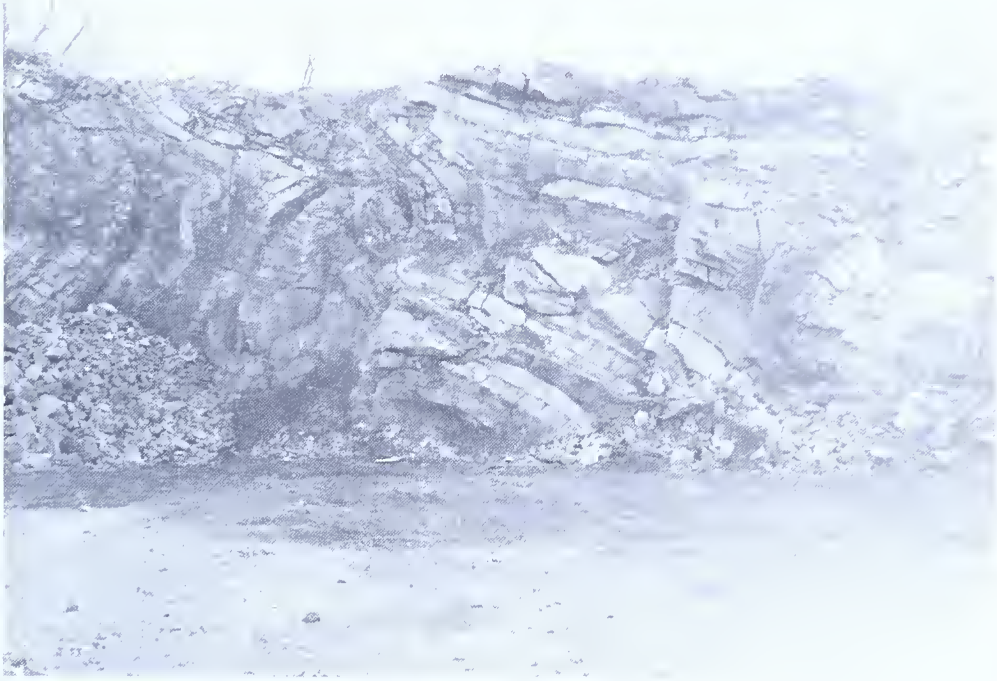

Figure 14. Complex folding of limestones and dolomites in the Epler Formation. Small quarry located on the southeast side of the Borough of Annville.

Faults

The largest fault within the carbonate rocks is the South Lebanon Thrust Fault. This thrust may be traced from the Lebanon-Berks Co. line to its intersection with the Triassic border southeast of Hummelstown in Dauphin County. In the Palmyra quadrangle, much of the Conocheague Group plus some of the Stonehenge and Buffalo Springs Formations are missing. It has been calculated that the minimum of several miles displacement exists. Faults are common in the Martinsburg Formation. In the area between Union Water Works and Bellegrove, limestone belts end abruptly at a line which is almost north-south (Moseley, 1954). A belt of red shale making up the top of a flat hill at this locality also ends at the same line. Strike-slip movement along this fault might be in the order of four-fifths of a mile.

About two and three-quarters miles northwest of Annville, a prominent hill rises abruptly from the flood plain of Quittapahilla Creek. The hill is composed of red shale, greenish-gray quartzite, and interbedded argillaceous sandstone and shale of the Martinsburg Formation in a tightly

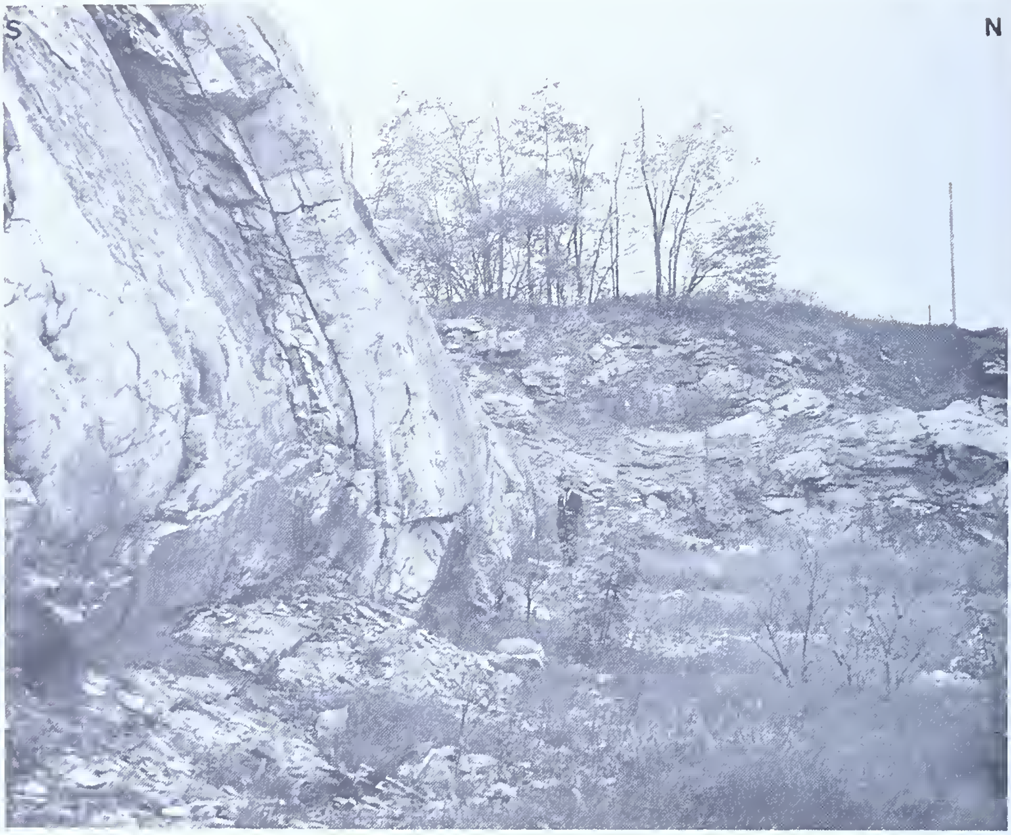

Figure 15. Recumbent folds in the Epler Formation. Small quarry is located approximately 1500 feet east of the quarry shown in Figure 14.

folded syncline. The hill and the syncline end just south of the westward-flowing tributary of Quittapahilla Creek. This abrupt cut-off is interpreted as a cross-fault which strikes east-west, almost perpendicular to the axis of the syncline.

The rocks of the syncline are apparently separated by a cross-fault on the east from adjacent limestone and shale. The limestone in turn is cutoff by a cross-fault so that it abuts Martinsburg red shale to the south. The evidence for their existence is the areal distribution of the blocks of rock and the offset ridges. The faults are interpreted as high angle dip cross-faults.

Moseley's manuscript maps of the Martinsburg Formation in Lebanon County show a distinct textural break and a lithologic change occurring approximately through the middle of the Martinsburg belt. Highly distorted structures in the Martinsburg occur south of this line. This break is also on strike with a thrust fault mapped in eastern Dauphin County by Carswell and Hollowell (1968). It is this major break that is interpreted as the Yellow Breeches Thrust by MacLachlan (1967). A complete analysis of this thrust zone is given by MacLachlan (1967). A small portion of this thrust zone appears to be present in the northwest corner of the Palmyra Quadrangle.

TRIASSIC LOWLAND SECTION

The regional structure of the Triassic rocks can be described as a homocline with moderately steep northward to northwesterly dips, intersected by faults and locally warped to form open anticlines and synclines.

In the Palmyra Quadrangle, an anticline and a syncline are superimposed on the north-dipping homocline. Minor cross-faults offset some of the conglomerate members. Faults occur along the north margin, but their displacement is believed to be small.

Folds

Colebrook Anticline

The curved strike of conglomerate members in the southeastern corner of the quadrangle indicates a plunging anticline with an axis striking nearly due north-south through Colebrook in the Elizabethtown Quadrangle. Dips on the northwest limb are about 35°. No exposures were found on the northeast limb but the spacing of the conglomerate member indicates approximately equivalent dips there, if similar thicknesses are assumed. The north margin truncates the anticline, and the uppermost conglomerate member is thereby interrupted. The eastern segment underlies the 900-foot high hill south of Fontana and the western one forms the ridge that trends southwestward south of Mount Pleasant.

Plainville Syncline

Southeast of Campbelltown, the rocks adjacent to the north margin are warped into a roughly symmetrical syncline whose axis trends nearly due east. Dips are between 30° and 40° on both limbs. Only one exposure was found on the north limb. It is in a road cut where the southerly dip was unmistakable when the cut was fresh. The north limb is outlined by a conglomerate member that forms a distinct ridge only one-fourth mile south of the north margin. The equivalent conglomerate on the south limb is thought to be an intermittent unit one-fourth mile south of Plainville. Unless there are undiscovered strike-slip faults, no member farther south could represent the horizon of this northern conglomerate. The syncline is truncated on the east by faults south of Garfield school, and on the west by the Triassic margin where it trends southwestward.

Faults

Minor faults with a north-south trend cut the Triassic rocks south of Mount Pleasant and south of Garfield School. An eastern fault is inferred from a conspicuous offset at the north margin and from truncated diabase in line with the offset. Faults south of Garfield School truncate or offset conglomerate units and diabase. Slickensided rock occurs at several places along the traces of the faults.

Southwest of Campbelltown two faults with a northwest strike displace the Triassic border. The eastern one offsets the Triassic margin about one-half mile, attesting either to large displacement or more probably to a gently sloping floor beneath that part of the Triassic basin. This fault also truncates diabase dikes (late Triassic or early Jurassic) that occur in the limestone but that do not continue into the Triassic sandstone.

The western fault is more clearly indicated. It causes a less prominent irregularity at the north margin but its course along the valley of a brook is marked by abundant slickensided rock. Near the southern edge of the quadrangle it truncates conglomerate. This fault is the most important in the Triassic area, marking the boundary between two large areas of discordant homoclinal structure. East of the fault, the dips are essentially northward, except for local southward dips at the north border, on the north limb of the Plainville syncline. West of the fault, the dips all are westward or somewhat south of west. The westerly dips continue into the Elizabethtown Quadrangle to the south for at least a mile and southwestward into the Middletown Quadrangle for more than a mile.

The Fault At The North Margin

From the eastern edge of the quadrangle to a point south of Campbelltown, the north border of the Triassic is fairly straight except for a fault offset south of Mount Pleasant. The straightness may suggest an important fault, and the fact that the border truncates the northward-plunging Colebrook anticline supports such an interpretation. Appreciable brecciation and slickensiding were seen on the bank of a brook near the bend of a minor road south of Campbelltown. Two exposures within a few yards of the border are so brecciated that bedding cannot be distinguished. At this locality, a fault at the margin definitely exists. However, the only clearly established movement post dates or is synchronous with sediment deformation and the intrusion of major diabase sheets. Direct evidence of a half-graben border fault previous to basin filling is lacking. The Plainville syncline may represent a drag fold adjacent to this fault, in which case a large displacement is possible. On the other hand, in view of the clear evidence of unconformable overlap at Cornwall (see Lapham and Gray, in preparation), a displacement of many thousands of feet should not be assigned to this north-margin fault without additional evidence.

The part of the north margin that trends southwestward in the western part of the quadrangle is interpreted as an unconformable overlap. Near the southwestern corner, the west-trending boundary is straight, continuing for 1.5 miles westward into the Hummelstown Quadrangle. Its course is perpendicular to the strike of Triassic sediments that dip steeply westward and the marginal disconformity truncates two conspicuous conglomerate members. Displacement here in the north margin fault increases westward, possibly to 3000 feet in the Hummelstown Quadrangle.

From the relationships south of Mount Pleasant, it is clear that faulting was episodic. Movement on the fault of the north margin probably occurred after diabase injection and after, or coincident with, folding.

MINERAL RESOURCES AND ENVIRONMENTAL GEOLOGY

HIGH-CALCIUM LIMESTONE

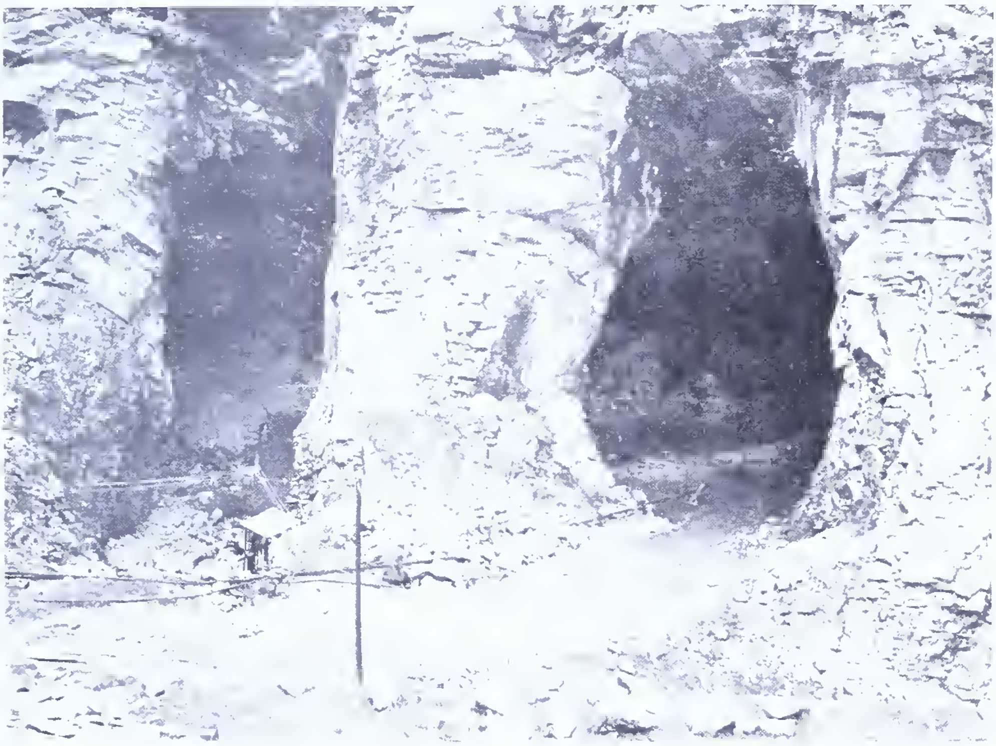

Figure 16. The Annville limestone underground mine northeast of Hershey and immediately west of The Palmyra quarry. View shows openings and supporting pillars of room-and-pillar mine.

The Annville Limestone is the only high calcium limestone present in the Palmyra Quadrangle. This formation reaches a maximum thickness of approximately 250 feet in the area. Analyses of the limestone indicate that the Annville here averages more than 96% calcium carbonate. Shipments of larger size stone commonly test over 97% calcium carbonate.

The Annville Limestone is currently being quarried for fluxstone, agricultural limestone, filler material, aggregate, roadstone, railroad ballast, and as a stone that is used to enrich cement rock. Chemical analyses of the Annville satisfy the requirements for cement limestone, fluxstone, agricultural limestone, and in some cases general chemical uses, filler, and lime.

No attempt has been made to calculate the reserves of high calcium limestone in this quadrangle. Recoverable reserves may be affected by many factors, such as local areas of excessive overburden, ground water and cultural features—urban and suburban development, railroads, and highways. Large additional reserves of high calcium limestone would be available in this area to underground mining.

Underground mining (Figure 16) is a method by which the high calcium limestone producer can obtain quality stone from the Annville Formation. Mining of this limestone has, to date, not been widely used in the Lebanon Valley. However, the advantages of mining the high calcium limestone are many.

1. Mining eliminates the removal of overburden. In the Annville district the clay soil overburden and the overlying Ontelaunee dolimite would not have to be removed. Underground mining is independent of weather conditions existing on the surface. The opposite is true in the quarry. Weather usually causes delay in open pit work. Winter snows in southeastern Pennsylvania are often times too deep in which to operate and the quarrymen often find the summer heat unbearable. Underground mining affords relief from both of the conditions.

2. A clean stone product is produced immediately from mining operations. Underground mining eliminates the process of washing the stone before shipment.

3. Lateral and vertical extent in mining the Annville Limestone are limited by the deposit itself and the costs of hoisting, pumping, etc. The Annville Limestone in the Palmyra Quadrangle maintains a semi-regular outcrop pattern and it shows no appreciable thinning at depth, making it an ideal formation to mine. Exploratory drilling should also prove the dip of the formation flattens out at depth.

4. Mines can operate under the valuable farm land of the Lebanon Valley. In the Annville-Palmyra district, this advantage is very im-

portant because the farm land of the Valley often sells for more than a $1000 an acre.

5. Finding available space for surface storage of the limestone is sometimes a problem, but in mining this problem can be solved by storing the limestone underground in an unused portion of the mine.

The size of the high calcium limestone deposit is a basic requirement that must be met before mining of such a deposit becomes feasible. Fortunately, this deposit in the Palmyra Quadrangle is a thick one (greater than 200 feet) and with extensive underground development this might compete successfully with any of the quarry operations to the east.

The dip of the deposit is another feature to consider in determining whether or not mining is feasible. Mining of inclined rocks is more costly than mining a flat deposit and therefore a mine in inclined rock must produce a larger volume of stone. The dips in the Annville Limestone in the Palmyra Quadrangle range from 30 to 50 degrees at the surface but tend to flatten out to almost horizontal at depth. Detailed geologic mapping shows that this limestone is thick enough to warrant underground mining if this factor alone were to be considered.

A strong, safe roof and pillars are essential to any limestone mining operation. A self-supporting roof is important because timbering is too costly to use in a low-price commodity such as limestone. In the Annville-Palmyra district the thick, massive Ontelaunee dolomite of the Beekmantown Group serves as the roof. In this case the high calcium limestone can be mined to its uppermost limits and no high-grade stone has to be left to form a roof. The pure high calcium limestone itself forms the roof supporting pillars. The dense, crystalline Annville Limestone is good for this purpose because it is strong and relatively unfractured and the size of the pillar can be kept to a minimum.

Today, many stone producers in the Lebanon Valley should consider underground mining operations. The conversion from quarrying to mining will soon become necessary because the good, quarryable deposits of high calcium limestone in strategic market locations are becoming scarce, and many of the present quarries have been worked out. The present plant facilities may be utilized on the site when this conversion takes place. The slightly higher cost of mining can be counterbalanced by increased volumes and quality of stone produced. Improved mechanization of mines is a factor steadily working toward lower cost per ton of recovered stone.

LIMESTONE AND DOLOMITE

Less pure limestone and dolomite formations are numerous in the quadrangle. One of the limestone formations and one dolomite formation are economically important.

The Epler Formation is a thick and continuous limestone and dolomite unit that occurs across the quadrangle. This unit has been a major source of crushed aggregate. It is presently quarried for this purpose at Palmyra and to the west at Steelton. Substantial reserves of this formation exist and should be comparable to that being actively produced. These reserves could be made available if demand warranted. Long term prospects suggest that the Epler Formation will be a continuing and increasingly important source of aggregate. Urban expansion in the Lebanon Valley should provide this demand.

The Ontelaunee Formation is more dolomitic than the Epler and it may yield a tougher, more desirable aggregate. To the west, several quarries are producing aggregate from the formation. The upper 200 feet of the Ontelaunee Formation has a potential value as a high-quality magnesiam stone. This part of the formation may become, in the future, a source of high-magnesium metallurgical-grade stone increasingly sought by the steel industry.

GROUND WATER

Carbonate Rocks

A very detailed ground water study was conducted in this area in 1963 by Harold Meisler of the U. S. Geological Survey. An inventory of municipal, industrial, and domestic wells and springs was made during this investigation. Short term pumping tests at low pumping rates were made to determine the relative specific capacities of the wells. In addition, groundwater samples were collected and complete chemical analyses of the samples were made. All of the information is published in Ground Water Report 18 of the Bureau of Topographic and Geologic Survey.

The following conclusions are those derived by Meisler (1963) for this quadrangle and the adjacent quadrangles to the east:

1. The most reliable sources of ground water are the Shafferstown and Millbach Formations of the Conococheague Group, and the Stonehenge and Ontelaunee Formations of the Beekmantown Group, and the Annville Limestone.

2. The least reliable sources of ground water are the Snitz Creek Formation of the Conococheague Group, the Epler Formation of the Beekmantown Group, and the Hershey Limestone.

3. The non-shaly limestone aquifers generally yield larger supplies of water to wells than do the dolomite aquifers.

4. The maximum porosity of the carbonate rocks occurs at some distance below the water table. Reported depths to waterbearing crevices in the Lebanon Valley range form 16 to 505 feet. Seventy-five percent

of the water bearing crevices were encountered at less than 145 feet. The maximum concentration of water bearing crevices and, hence, maximum porosity is between 70 and 80 feet below the land surface.

5. Ground water in the carbonate rocks is of the calcium bicarbonate type. Nitrate contamination is common and many samples taken in this recent study contained more than 45 ppm nitrate, which is the maximum nitrate content considered acceptable by the U. S. Public Health Service. An east-west trending belt, approximately one mile north and one mile south of Route 422, shows a significant nitrate contamination. This nitrate contamination is probably the result of contamination from urban and industrial waste disposal.

The groundwater potential for each carbonate formation is given in the explanation to the Geologic Map, Plate 1.

The high purity of the Annville Limestone makes it particularly susceptible to the formation of large solution cavities which in turn makes it one of the leading aquifers of the area. In mining, however, this groundwater has been a major problem. Almost every large quarry in the Annville belt of Lebanon and Dauphin Counties has to cope with extremely large quantities of water. In some cases pumping costs become excessive. In the underground mining of this high calcium limestone, this problem is even more accute. Before mining operations are begun, quarry operators must seek an effective control of the groundwater.

In the past, grouting had been attempted several places with fair results obtained from each attempt. The problem, however, with this method is that after a short period of reduced flow, the water found new openings and returned the flow to the mine to the near normal. The largest concentrations of ground water in the existing mines tend to be at intersections of faults or the intersection of a solution channel with a fault. An example of this could be seen in the west end of the west quarry formally owned by the Michigan Limestone Division of United States Steel Corporation immediately to the west of the Palmyra Quadrangle. Here the ground water was flowing out of a zone along the fault trace at the rate of several thousand gallons per minute. Other examples of this could be seen at a number of places in this mine.

Although much has been written about the ground water and soils of a limestone terrane as well as the importance of limestone and dolomite as a valuable mineral resource, very little information is available on the hazards present in carbonate rocks. These hazards occur because carbonate rocks are subject to solution on the surface and in the subsurface, with the development of caves and sinkholes. Figure 17 shows a diagrammatic crosssection through an area with solution of the carbonate bedrock.

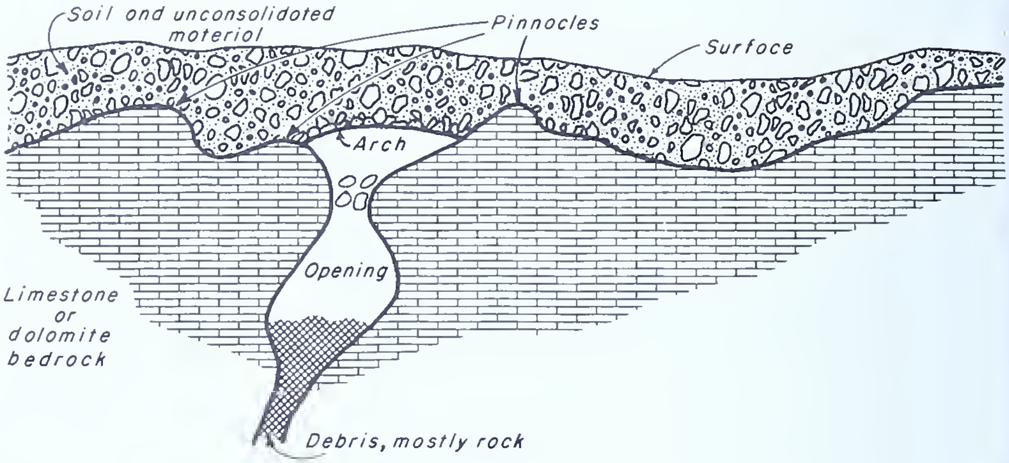
Soil and unconsolidated material
Pinnacles
Surface
Arch
Opening
Limestone or dolomite bedrock
Debris, mostly rock

Figure 17. Hypothetical cross section through sink hole.

The sketch shows pinnacle or jagged and rough weathering as opposed to a smooth surface on top of the bedrock. When the overlying soil and unconsolidated material dry-out, downward migration of soil debris into solution cavities takes place. The arch over the solution opening tends to migrate upward as material gradually falls into the opening. Collapse may occur when unusually heavy load conditions exist over the arch causing the arch to break. A heavy rainstorm that saturates the soil and weakens the arch may act as the trigger for the collapse. A catastrophic type of collapse can occur above the areas of pinnacle or jagged bedrock whereas a general subsidence is likely over areas of a smooth surfaced bedrock. Sinkholes of the catastrophic type are usually steep or vertically walled and may range from 5 to 10 feet to an excess of 100 feet deep.

Areas in danger of collapse by sinkhole development are extremely important in considering the foundation requirements for highways, dams, bridges and high-rise buildings. As the population increases and shifts to suburban districts, more and more of the carbonate bedrock area in the Palmyra Quadrangle and elsewhere in Pennsylvania will be the site of extensive road building, industrial development and private housing expansion. It is important to be aware of the potential hazards present in these carbonate rocks in order that proper testing and planning will precede construction.

Martinsburg Formation

A detailed ground water study of the Martinsburg Formation was completed and published in 1968 for an area immediately west of the Palmyra Quadrangle. The rock types studied in the Martinsburg Formation were chiefly shales and shaly siltstones. Minor types included siliceous shales, thin bedded shaly limestones, limestone conglomerates, clayey dolomites, sandstones, and graywackes. Carswell and Hollowell (1968) found in their study of the Martinsburg Formation the following:

1. The upland stream valleys are the most favorable topographic locations for obtaining the highest-yielding wells. Ground water is stored and moves through these rocks in openings along joints, faults, and bedding planes.
2. As depth increases, fracture openings in the Martinsburg rocks decrease in number and size. Most wells yield water from zones that are less than 200 feet deep.
3. Well development by adding a chemical cleaner (chiefly hexametaphosphate) and surging proved to be an effective tool for increasing well yields. Simple well development by surging and bailing improved a well as much as 67% and by adding a chemical cleaner and surging, a well was improved an additional 40%.
4. North of the Yellow Breeches Thrust Fault, yields of 10 to 50 gpm are common.
5. South of this fault, wells commonly yield 10 gpm or less. In this area, the highest yielding wells (50 to 200 gpm) are in the limestones of the Martinsburg.

The conclusions reached by Carswell and Hollowell (1968) for the Martinsburg Formation in Dauphin County appear to be valid for the Palmyra Quadrangle.

Hammer Creek Formation

The Hammer Creek Formation consists primarily of fine- to coarse-grained quartzose sandstone and red shale with interbedded quartz pebble conglomerate in the Palmyra Quadrangle. No detailed ground water studies have been made of this formation but generalities concerning it are obtained from the data collected by Seaber and Hollyday (1965) for the Lower Susquehanna River Basin.

1. Most wells in this formation range in yield from 55 to 480 gpm. Fifty percent of all the successful wells inventoried yielded 160 gpm or more.

2. Maximum yields may be realized from wells drilled to 400 feet deep and 10 inches in diameter.
3. The water is of good quality for most uses. It is low to moderate in dissolved solids, hardness, and iron content.
4. Topographic low areas are the best sites for wells in this formation. The ground water table is nearer the land surface in stream valleys and the area of recharge is greater.

Two positive steps toward the solution of various groundwater problems in Lebanon and Dauphin Counties have been completed recently. Through a cooperative program between the U.S. Geological Survey, Water Resources Division, and the Pennsylvania Geological Survey a detailed study of the hydology and geology of the Lebanon Valley has been completed (Meisler, 1963). This project, *The Hydrogeology of the Carbonate Rocks of the Lebanon Valley* (Bulletin W-18, Pennsylvania Geological Survey) has developed valuable data that will be equally useful to those people looking for more water as well as those interested in controlling the excessive flow of water. This study was a quantitative treatment of the entire district and should provide valuable data to those quarry operators who in the future may want to change some quarrying to underground mining or to a Borough or City that wants to closely define potential hazardous areas of carbonate rocks.

The second study (Stuart, 1967) that should benefit the Palmyra area is one that was released early in 1968—*The Swatara Creek Basin of Southeastern Pennsylvania—An Evaluation of its Hydrologic System*—by the U.S. Geologic Survey. It has been said that the Swatara Creek and its many tributaries are a hydrologic system that when developed as a unit can provide an abundant water supply to meet all present and most future needs in the basin. The report summarizes our present knowledge of the sources of water in the Swatara Creek basin, the natural features of the basin controlling the behavior of the water, man's influence, and the problems arising from man's activities. There exists in the basin a relationship of distribution and movement of water through the basin in such a manner that when modification of any part of the system is made, the effects will be known in other areas. As decisions for future development are made, the effects of such changes can be anticipated and the alternate choices can be considered.

Using this report as a guide, those managing the water resources may be able to help alleviate some problems and prevent others. On the basis of hydrologic knowledge furnished in this report, the greatest benefits will accrue if actions taken to obtain water are not detrimental to the hydrologic system as a unit.

SHALE

Early in 1962, investigation into the property and uses of Pennsylvania's shales and clays was initiated. Shale samples were collected from outcrops, roadcuts, and quarries throughout the Commonwealth from many different geologic units. Tests were performed on these samples at the Norris Metallurgical Research Laboratory of the U.S. Bureau of Mines in Norris, Tennessee.

Several samples were collected from the Martinsburg Formation in the Palmyra Quadrangle for this study. The chemical and physical data for each sample (O'Neill and others, 1965) are given below.

Sample Number

157-6-1A

Quadrangle: Hummelstown 15′; Palmyra 7½′

Location: Exposure along the east side of State Route 934 about 0.8 mile northwest of Annville.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Pale-red-purple shales with some beds of greenish-gray shales, measuring sixty stratigraphic feet, are exposed along the roadway from 70 to 130 feet north of telephone pole ME IC 5781. The height of the exposure in this section is from 2 to 20 feet.

Attitude of Bedding: N80W; 84N

Sampled Interval: Composite sample representing 60 stratigraphic feet of section.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	60.00
Al_2O_3	19.70
Fe_2O_3	5.97
FeO	2.46
CaO	.07
MgO	.98
K_2O	5.00
Na_2O	.52
TiO_2	.82
L.O.I.	4.41
S	.004
CO_2	.26
comb. H_2O	4.15

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	32	8
Mica	47	8
Kaolinite	8	6
C-V-Mo	4	3
Feldspar	0	3

Other Tests:

pH: 7.9

Workability: not plastic, short and mealy

Water of plasticity %: 17.0

% Drying shrinkage: 1.0

Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Sandy brown	Soft, crumbly	1.0	14.3	2.75
1900	Sandy brown	Soft, crumbly	1.0	12.6	2.73
2000	Brown	Fairly hard	2.5	9.9	2.70
2100	Dk. Brown	Hard	2.5	8.0	2.69
2200	Gray black	Steel hard	2.5	5.8	2.59
2300	Melted and expanded				

Bloating Test: Slight

Potential Uses: Possibly brick and sintered aggregate.

Sample Number
157-6-1B

Quadrangle: Hummelstown 15′; Palmyra 7½′

Location: Exposure along the east side of State Route 934 about 0.8 mile northwest of Annville.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Sixty stratigraphic feet of gray-red and purple shales are exposed south of telephone pole marked ME K 5783. This section represents the northern portion of an exposure which extends for a distance of over 550 feet along the roadway.

Attitude of Bedding: N80W; 84N

Sampled Interval: Composite sample from sixty stratigraphic feet of section.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	62.50
Al_2O_3	17.05
Fe_2O_3	5.38
FeO	1.77
CaO	.11
MgO	1.34
K_2O	6.00
Na_2O	.26
TiO_2	.95
L.O.I.	4.58
S	.008
CO_2	.33
comb. H_2O	4.25

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	32	8
Mica	51	8
Kaolinite	0	3
C-V-Mo	3	2
Feldspar	1	2

Other Tests:

pH: 7.8
Workability: not plastic, short and mealy
Water of plasticity %: 19.0
% Drying shrinkage: 1.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	1.0	17.2	2.67
1900	Dk. buff brown	Soft, crumbly	2.5	13.8	2.61
2000	Dk. brown	Fairly hard	5.0	8.3	2.59
2100	Dk. Brown	Hard	7.5	4.9	2.54
2200	Dk. brown	Steel hard	Exp.		
2300	Melted and expanded				

Bloating Test: Slight

Potential Uses: Possibly brick and sintered aggregate.

Sample Number
157-6-1C

Quadrangle: Hummelstown 15′; Palmyra 7½′

Location: Exposure along the east side of State Route 934 about 0.8 mile northwest of Annville.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Forty stratigraphic feet of moderate-yellow-brown and gray-orange, thin-bedded shales are exposed to the south of a point about 60 feet south of telephone pole marked ME K 5783. The height of the exposure is about 10 feet.

Attitude of Cleavage: N65E; 45S

Sampled Interval: Composite sample taken from forty stratigraphic feet.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	61.40
Al_2O_3	17.30
Fe_2O_3	6.42
FeO	1.44
CaO	.12
MgO	1.19
K_2O	5.10
Na_2O	.55
TiO_2	.88
L.O.I.	5.53
S	.01
CO_2	.40
comb. H_2O	4.76
H_2O @ 120°C	.37

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	34	8
Mica	52	10
Kaolinite	1	3
C-V-Mo	3	3
Feldspar	1	3

Other Tests:

pH: 7.7
Workability: not very plastic, short and mealy
Water of plasticity %: 22.0
% Dry shrinkage: 3.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	5.0	19.7	2.71
1900	Dk. buff brown	Soft, crumbly	6.0	16.2	2.69
2000	Dk. brown	Fairly hard	10.0	8.3	2.61
2100	Dk. brown	Hard	11.0	5.2	2.58
2200	Very dk. brown	Steel hard	11.0	2.8	2.48
2300	Gray black	Steel hard	Exp.		

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: $-\frac{1}{2} + \frac{1}{4}''$

Drying characteristics: Good Retention time: 15 Min.

Temp. °F.	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	2.26	140.8	5.0	No bloating
2000	2.44	152.0	2.3	No bloating
2100	2.09	130.2	2.6	Slight bloating
2200	1.30	81.0	3.0	Fair bloating

Evaluation: Poor results may be due to the amount of weathered shale in the sample.

Potential Uses: Possibly brick.

Sample Number
157-6-2

Quadrangle: Hummelstown 15′; Palmyra 7½′

Location: Exposure along the east side of State Route 934 near the southern boundary of Bellegrove, about 2.7 miles northwest of Annville.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Moderately weathered shales of the Martinsburg Formation are exposed in a roadcut for a distance of about 200 feet. The colors of the shale range from light olive gray to yellow gray.

Attitude of Bedding: Strike approximately EW, dips steeply south

Sampled Interval: Composite sample from entire exposure

Type of Material: shale

Chemical Analysis:

	%
SiO_2	57.50
Al_2O_3	19.60
Fe_2O_3	7.23
FeO	1.77
CaO	.19
MgO	1.20
K_2O	4.08
Na_2O	.43
TiO_2	1.02
L.O.I.	6.94
S	.014
CO_2	.55
comb. H_2O	6.39

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	33	8
Mica	45	8
Kaolinite	1	3
C-V-Mo	12	5
Feldspar	0	3

Other Tests:

pH: 7.4
Workability: not plastic, short and mealy
Water of plasticity %: 24.0
% Drying shrinkage: 1.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Skh.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	4.0	21.8	2.76
1900	Dk. buff brown	Soft, crumbly	4.0	19.1	2.73
2000	Med. brown	Fairly hard	7.5	12.0	2.62
2100	Dk. brown	Hard	8.0	10.4	2.62
2200	Dk. brown	Very hard	8.0	7.4	2.55
2300	Gray black	Steel hard	Exp.		

Bloating Test: Negative

Potential Uses: Possibly brick.

Sample Number
157-6-3

Quadrangle: Hummelstown 15′; Indiantown Gap 7½′

Location: Exposure along the east side of State Highway 934 about 4.3 miles northwest of Annville.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Grayish-red to moderate-red shale, much of which has weathered grayish-orange, is exposed for a distance of several hundred feet along the roadcut. The height of the exposure is from six to seven feet

Attitude of Bedding: N45E; 40SE

Sampled Interval: Composite sample from southern half of the exposure.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	57.00
Al_2O_3	20.94
Fe_2O_3	8.01
FeO	1.04
CaO	.12
MgO	.93
K_2O	4.10
Na_2O	.83
TiO_2	.92
L.O.I.	6.08
S	.01
CO_2	.26
comb. H_2O	4.97
H_2O @ 120°C	.85

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	40	10
Mica	44	10
Kaolinite	1	3
C-V-Mo	3	2
Feldspar	1	3

Other Tests:

pH: 7.2
Workability: not very plastic, short
Water of plasticity %: 20.0
% Drying shrinkage: 1.5
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	3.5	18.0	2.75
1900	Dk. buff brown	Soft, crumbly	5.0	14.6	2.73
2000	Brown	Fairly hard	7.5	10.2	2.69
2100	Dk. brown	Hard	10.0	6.5	2.64
2200	Dk. brown	Very hard	10.0	4.8	2.58
2300	Gray black	Steel hard	10.0	4.1	2.53
**2000		Steel hard	4.7	3.4	2.66
**2050		Steel hard	6.3	1.2	2.61

** Additional firing data on miniature pressed brick with a two hour soak.

Bloating Test: Negative

Potential Uses: Brick.

IRON

Between Cornwall and the Susquehanna River there are two minor occurrences of magnetite ore. One of these is the old Carper mine located about one mile south-southeast of Mount Pleasant in the southeast corner of the Palmyra Quadrangle while the other is located to the west in the Hummelstown Quadrangle.

Approximately 1,500 tons of ore have been mined from the Carper deposit. The mine lies along a fault at the north margin of the Triassic basin in approximately the same position stratigraphically as the Doner Mine at Cornwall (i.e., in units lying below sheet diabase). North of the ore pit the rocks are limestones and dolomites of the Buffalo Springs Formation. Diabase lies to the south.

In 1908, Spencer postulated that the ore should persist in depth and should also occur at other points along this fault both east and west of the old mine. However, in 1957 the Pennsylvania Geological Survey in cooperation with the U. S. Geological Survey flew an aeromagnetic survey of this area (Bromery, 1961) and failed to find any anomaly in the vicinity other than that exhibited by the diabase itself. This would tend to eliminate the possibility of a large ore body buried at depth, depending to some extent on the orientation of the remanent magnetization.

From the field relationships, the simplest interpretation of the margin-parallel fault is that it transects sheet diabase and is the fault intruded by ore (see Spencer, 1908). If these interpretations are correct, the time of ore introduction is separated from that of diabase injection by one or more periods of faulting, similar to the sequential relationships found at Cornwall (Lapham and Gray, in preparation).

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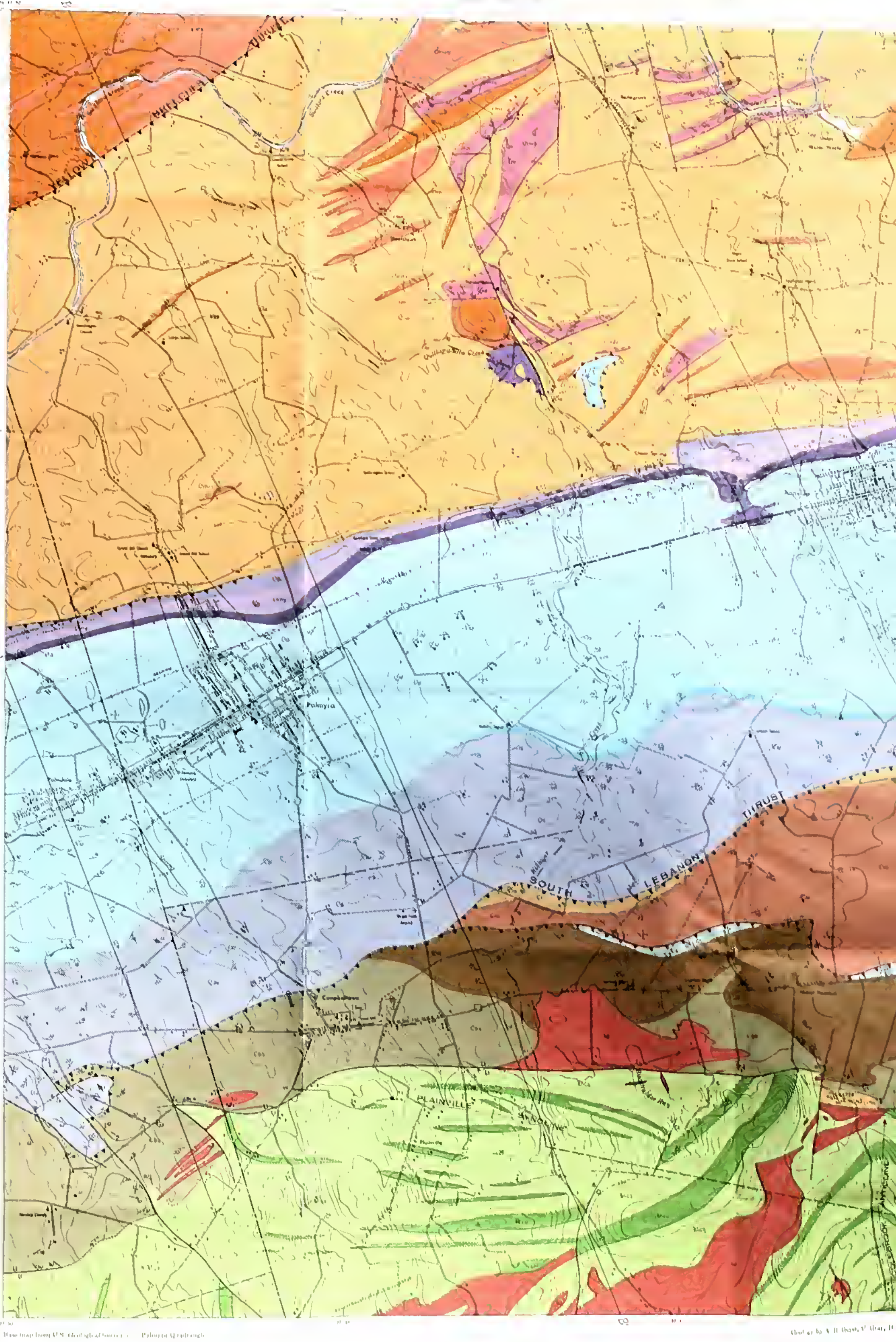
TOPOGRAPHIC & GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

ENVIRONMENTAL GEOLOGIC FACTORS

ENGINEERING PROPERTIES	FORMATION	GROUNDWATER AVAILABILITY
The following information on the rocks of this quadrangle should be useful to engineers and land-use planners. Much of this information is basic data needed for planning most engineering construction jobs. Any manmade structure should be adapted to the topographic and geologic environment shown and discussed in this report.		
[illegible]	**DIABASE**	[illegible]
[illegible]	**HAMMER CREEK** (sandstone, quartz conglomerate and shale)	[illegible]
[illegible]	**MARTINSBURG** (shale, minor sandstone and limestone)	[illegible]
[illegible]	**HERSHEY** (limestone)	[illegible]
	MYERSTOWN (limestone)	[illegible]
[illegible]	**ANNVILLE** (limestone)	[illegible]
[illegible]	**ONTELAUNEE** (dolomite and minor limestone)	[illegible]
[illegible]	**EPLER** (limestone and dolomite)	[illegible]
[illegible]	**RICKENBACH** (dolomite and minor limestone)	[illegible]
[illegible]	**STONEHENGE** (limestone and dolomite)	[illegible]
[illegible]	**RICHLAND** (sandy dolomite and limestone)	[illegible]
[illegible]	**MILLBACH** (limestone and dolomite)	[illegible]
[illegible]	**SCHAEFFERSTOWN** (limestone)	[illegible]
[illegible]	**SNITZ CREEK** (sandy dolomite and limestone)	[illegible]
[illegible]	**BUFFALO SPRINGS** (limestone and dolomite)	[illegible]

WELL DEPTHS SHOULD NOT EXCEED 200 FEET

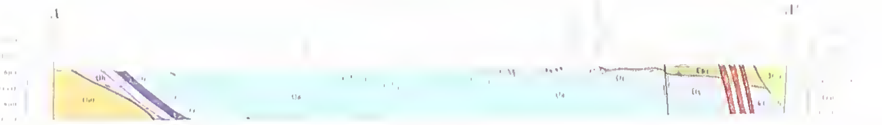


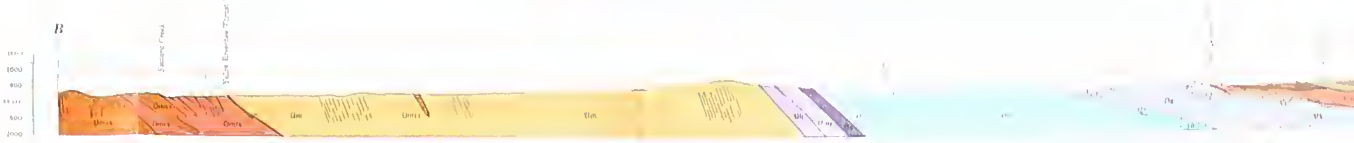
Location diagram with index
of areas mapped by co-workers

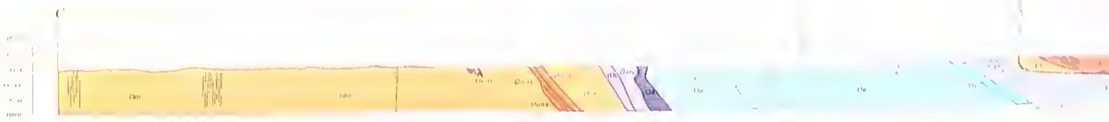
GEOLOGIC MAP OF THE PALMYRA QUADRANGLE

1970

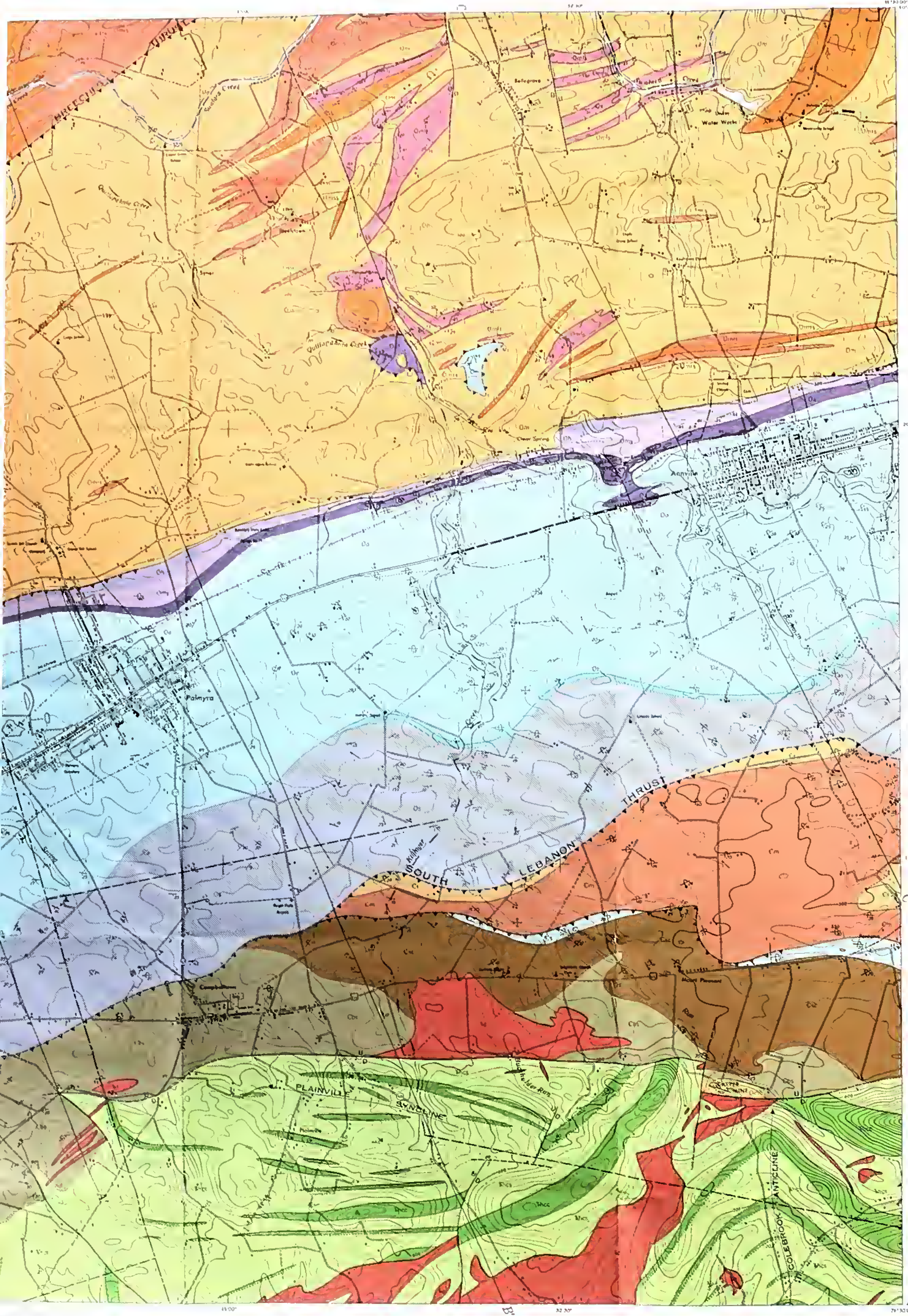
GEOLOGIC CROSS SECTIONS







COMMONWEALTH OF PENNSYLVANIA
STATE PLANNING BOARD
Irving Hand, Executive Director



Geology by A. R. Geyer, C. Gray, D. B. McLaughlin and J. R. Moseley

GEOLOGIC MAP OF THE PALMYRA QUADRANGLE

1970

MAP LEGEND

SYSTEM · SERIES · GROUP · MAP UNIT AND DESCRIPTION · LITHOLOGY Scale 1" — 500' · MAP SYMBOL

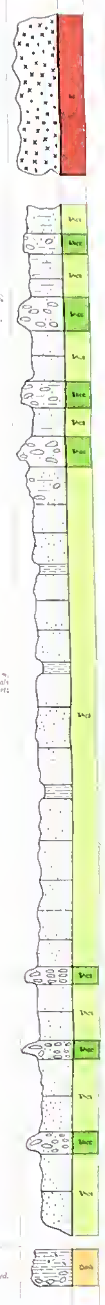
TRIASSIC · NEWARK GROUP

DIABASE
Medium coarse grained, dark gray, composed chiefly of gray plagioclase feldspar and black or green augite. Intrudes Triassic and Paleozoic sediments.

HAMMER CREEK FORMATION

QUARTZ CONGLOMERATE
(Trhcc)
Interbedded quartz cobble conglomerate and red sandstone

SANDSTONE
(Trhc)
Fine to coarse, red and brown, quartzose sandstone with a few red shale interbeds and thin bands of quartz pebble conglomerate



ORDOVICIAN · UPPER ORDOVICIAN?

MILL HILL SLATE
Hornfels & breccia undifferentiated.

ORDOVICIAN · UPPER ORDOVICIAN

MARTINSBURG FORMATION
Light gray to medium gray shale (Om), argillaceous sandstone and quartzose sandstone (Omss), red shale (Omr), and interbedded gray shale and platy limestone (Omls)

ORDOVICIAN · MIDDLE ORD.

HERSHEY LIMESTONE
Dark gray, argillaceous limestone, thin bedded; grades upward into shale

MYERSTOWN LIMESTONE
Medium gray limestone, thin bedded; black graphitic limestone at base of formation

ANNVILLE LIMESTONE
Light gray limestone, high-calcium; massive bedded

ORDOVICIAN · LOWER ORDOVICIAN · BEEKMANTOWN GROUP

ONTELAUNEE FORMATION
Medium gray to dark gray dolomite; massive bedded, chert at base

ELPER FORMATION
Medium gray limestone interbedded with medium gray dolomite, cherty, fossiliferous, contains calcarenite beds

RICKENBACH FORMATION
Medium gray dolomite, cherty; sandy and laminated.

STONEHENGE FORMATION
Medium light gray limestone, cherty, thin shaly beds and laminations, "flat-pebble" breccia beds

CAMBRIAN · UPPER CAMBRIAN · CONOCOCHEAGUE GROUP

RICHLAND FORMATION
Medium gray dolomite, cherty; oolitic, sandy, some "flat-pebble" breccia beds.

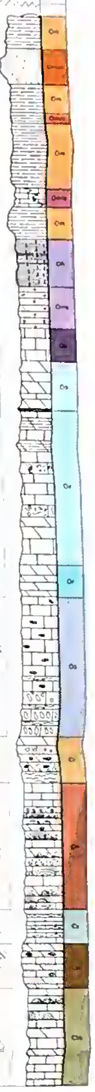
MILLBACH FORMATION
Pale red purple to light gray limestone, laminated; oolitic; cryptozoon reefs, interbedded dolomite.

SCHAEFFERSTOWN FORMATION
Medium light gray limestone, laminated; medium bedded

SNITZ CREEK FORMATION
Medium gray dolomite, sandy, laminated, cherty.

CAMBRIAN · MIDDLE CAMBRIAN ?

BUFFALO SPRINGS FORMATION
Light to pinkish gray limestone, cryptozoon reefs; sandy, interbedded dolomite; laminated.



SYMBOLS

(Symbols used in lithologic column)

COMPOSITION

- ▦ Limestone
- ▨ Dolomite
- ▦ Argillaceous
- ▦ Quartzose
- ▦ Cherty

TEXTURE

- ▦ Limestone fragments
- ▦ Fossil debris (crinoid, shells)

STRUCTURE

- ▤ Regular laminae and bands
- ▤ Irregular laminae and bands, streaks
- ▬ Chert beds
- ▦ Stromatolites
- ▦ Chert nodules and stringers

SYMBOLS

CONTACTS

Definite contact

Inferred contact

Concealed contact

STRUCTURE SYMBOLS

High angle fault, movement - U, up, and D, down

Fault, showing relative movement

Thrust, barbs on side of upper plate

Strike and dip of beds known to be right side up

Strike and dip of beds where it is not known which side is up

Horizontal bedding

Strike of vertical beds

Strike and dip of overturned beds

Strike and dip of cleavage

Horizontal cleavage

Strike and plunge of axis of mappable syncline

Strike and plunge of axis of mappable anticline

Strike and plunge of minor anticline, showing degree of plunge

Strike and dip of axial plane of minor overturned anticline

Strike and dip and beds rotated more than 180°

Strike and dip of joints

Strike of vertical joints

Horizontal joints

Trend of "smear" lination developed on bedding plane

MISCELLANEOUS SYMBOLS

Quarry or Mine

Fossil occurrence

A —— A'
Line of cross section

GEOLOGIC CROSS SECTIONS